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ABSTRACT

This military-developed text consists of self-instructional materials dealing with the basic tools and equipment used in metalworking shops. Covered in the individual lessons are the following topics: materials and processes; shop mathematics; blueprint reading and sketching; handtools, measuring instruments, and basic metalworking machines; vertical cutting bandsaws; shapers; milling machines; and lathes. Each lesson contains objectives, coded text, and exercises. Designed for immediate feedback, the exercise answers provide for rerouting to extra reading in case of incorrect answers and for reinforcement in the case of a correct answer. (MN)

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5

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

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- Evaluating individual program needs and outcomes
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- Operating information systems and services
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

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MACHINE SHOP PRACTICE

Table of Contents

Course Description Page 1

Machine Shop Practice - Course Program

Lesson 1 - Materials and Processes Page 6

Lesson 2 - Shop Mathematics Review Page 50

Lesson 3 - Blueprint Reading & Sketching Page 73

Lesson 4 - Handtools, Measuring Instruments And Basic Metalworking Machines Page 110

Lesson 5 - Vertical Cutting Bandsaw Page 211

Lesson 6 - Shaper Page 228

Lesson 7 - Milling Machine Page 247

Lesson 8 - Lathe Page 281

Exercise Response List Page 370

Examination Page 405

MACHINE SHOP PRACTICE

Correspondence Course 13-2

Developed by:

United States Army

Development and Review Dates

October 1973

Occupational Area:

Machine Shop

Cost:

Print Pages:

411

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Lesson objectives, readings, review questions and programmed answers; course examination

Type of Instruction:

Individualized, self-paced

Type of Materials:			**No. of Pages:**	**Average Completion Time:**
Machine Shop Practice				
Lesson 1	—	Materials and Processes	44	Flexible
Lesson 2	—	Shop Mathematics Review	23	Flexible
Lesson 3	—	Blueprint Reading and Sketching	37	Flexible
Lesson 4	—	Handtools, Measuring Instruments, and Basic Metalworking Machines	101	Flexible
Lesson 5	—	Vertical Cutting Bandsaw	17	Flexible
Lesson 6	—	Shaper	19	Flexible
Lesson 7	—	Milling Machine	34	Flexible
Lesson 8	—	Lathe	91	Flexible
Examination			8	

Supplementary Materials Required:

None

Course Description

This course was designed to give the student background information on the basic tools and equipment used in a metalworking shop. It is not intended to cover all the machines used or train the student to become a machinist. However, it does provide the job knowledge required in a metalworking shop. This course is divided into eight lessons covering the following topics:

Lesson 1 — *Materials and Processes* identifies the types, uses, properties, and capabilities of metals; explains the different processes used to produce metals; discusses the various tests used to identify the types and hardness of metals; and explains the purpose and outlines the procedures for the heat treatment of metals.

Lesson 2 — *Shop Mathematics Review* explains how to work, use, solve, explain and compute elementary mathematical problems used in shopwork applications such as equations and formulas, ratio and proportion, area and volume, square root, and linear and metric measurements. Angles, right triangles, and the Pythagorean Theorem are also covered.

Lesson 3 — *Blueprint Reading and Sketching* discusses how to read blueprints used in the metalworking shop and explains how sketches are used for conveying ideas to other people and technicians.

Lesson 4 — *Handtools, Measuring Instruments, and Basic Metalworking Machines* identifies and describes the uses and care of handtools and measuring instruments common to machine shop practice, and describes basic metalworking machines such as hand and bench grinders, portable electric drills, drill presses, and portable hacksawing machines.

Lesson 5 — *Vertical Cutting Bandsaw* explains the history, development, types, use, nomenclature and operation of the bandsaw. Attachment types, use, selection, care and cleaning are also discussed.

Lesson 6 — *Shaper* discusses the history, types, use, nomenclature, capabilities, and operation of shapers; shaper accessory attachments including cutting tools, cutting tool holders, and the swivel vise, rotary table, and indexing fixture; shaper functions such as setting cutting speeds and strokes, horizontal planing, angular planing, internal slotting, and planing irregular surfaces.

Lesson 7 — *Milling Machine* discusses the history, types, use, nomenclature, and operation of milling machines; types, use, selection, mountings, care, and maintenance of accessory components; and the various functions of the milling machine.

Lesson 8 — *Lathe* discusses the origin, history, purpose, types, use, nomenclature, and operation of the lathe; types, use, mounting and care of lathe accessory attachments; and the various functions that can be performed on the lathe.

Each lesson contains objectives, coded text, and exercises. The exercise answers are designed for immediate feedback: rerouting to extra reading in case of incorrect answer and reinforcement in the case of a correct answer. The course is designed for student self-study and evaluation. A course examination is provided but no answers are available. This course can be used as an introductory unit in machine shop courses.

3

CORRESPONDENCE COURSE
of the
US ARMY ORDNANCE
CENTER AND SCHOOL

ORDNANCE SUBCOURSE NUMBER
424

MACHINE SHOP PRACTICE

OCTOBER 1973

13-2

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

ORDNANCE SUBCOURSE NUMBER 424, MACHINE SHOP PRACTICE
(19 Credit Hours)

INTRODUCTION

The age we live in has been called the mechanical age. This is understandable when we realize that nearly everything we use in our present-day living is, more or less, machine made. The age, therefore, being mechanical, needs men with mechanical knowledge — knowledge of metals and how to shape them to man's needs. Considering the mechanical age, then, a few trades are obviously largely responsible for the current standard of living. Within this small group of trades are those which we will consider in this subcourse. Categorically, we can speak of these trades collectively as metalworking. Individually, we would have reference to machine shop practice.

Most machine tools have their origin in the Industrial Revolution in England and America from the mid-18th century to the mid-19th century. The invention of the steam engine by James Watt in 1774 was impractical until John Wilkinson, in 1775, developed a boring mill with which cylinders for the steam engine could be produced with sufficient accuracy. From that time onward, most machine tools were invented to satisfy a particular need.

Each machine tool can be traced to a basic named tool that has, in many cases, been in use for thousands of years. The early lathe was basically an adaptation of the ancient potter's wheel and the knife. The ancient Egyptian bow drill and later the brace and bit evolved into the drilling machine. In a similar manner, the milling machine replaced the file, the planer and shaper replaced the chisel and the scraper, and the sawing machines supplanted the handsaw.

What, then, is a metalworking shop? The answer is simple, but important; it is a place where metal parts are made to the size and shape required and put together to form mechanical units or machines.

This subcourse will enable you to learn the basic tools and equipment used in a metalworking shop. It is not intended to cover all the machines used or to make you a machinist, but it will give you a job knowledge of a metalworking shop.

This subcourse consists of eight lessons and an examination, organized as follows:

Lesson 1 Materials and Processes
Scope — Properties, types, and processing of metals.

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Lesson 2 Shop Mathematics Review
Scope — Review of equations, formulas, ratio and proportion, square root, linear measurements, area and volume, and other basic mathematic procedures.

Lesson 3 Blueprint Reading and Sketching
Scope — To familiarize you with the techniques used in blueprint reading and sketching used in a metalworking shop.

Lesson 4 Handtools, Measuring Instruments, and Basic Metalworking Machines
Scope — Familiarization, types, uses and care of handtools, measuring instruments, and basic metalworking machines.

Lesson 5 Vertical Cutting Bandsaw
Scope -- Nomenclature, types, operation, and handsaw blades and accessories used in vertical bandsaw operations.

Lesson 6 Shaper
Scope — Nomenclature, operation, and capabilities of the shaper.

Lesson 7 Milling Machine
Scope -- Nomenclature, operation, and capabilities of the milling machine.

Lesson 8 Lathe
Scope — Nomenclature, operation, and capabilities of the lathe.

Examination

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
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LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 424 . . . . Machine Shop Practice

Lesson 1 . . . . Materials and Processes

Credit Hours . . . . Three

Lesson Objective . . . . After studying this lesson you will be able to:

1. Discuss and identify metals as to types, uses, properties, and capabilities.
2. Explain the different processes used to produce metals.
3. Discuss the various tests used to identify metals as to types and hardness.
4. Explain the purpose and outline the procedures for heat treatment of metals.

Text . . . . Attached Memorandum

Materials Required . . . . None

Suggestions . . . . Visit a steel mill, if possible, and observe the operation of a blast furnace, open hearth, Bessemer converter, and rolling and drawing mills.

STUDY GUIDE AND ATTACHED MEMORANDUM

SECTION I. INTRODUCTION

1. The use of wood and stone as a basic material in the manufacturing of products is much older than the use of metal. Metal has, however, surpassed both of these materials. The reason for this increase in the use of metal lies in its characteristic properties. The most important of these properties are strength (the ability to support weight without bending or breaking) and toughness (the ability to bend rather than break when a sudden blow is applied). Resistance to atmospheric destruction, plasticity, and the ability to be formed into almost any shape adds to the combination of properties that are obtained in no other class of materials. Some types of metals have two additional properties: namely, the ability to conduct electric current and the ability to be magnetized.

2. Metals can be cast into many varied and intricate shapes ranging in size from a few ounces to many tons. The characteristic of plasticity, or the ability to deform without rupture, makes them safe to use in all types of structures and allows their formation into required shapes through forging and other operations. Metal also has the ability to be welded and, as such, is the only engineering material that is truly repairable.

SECTION II. PROPERTIES OF METALS

3. DEFINITION OF A METAL.

a. Before going into the discussion of the properties of metals, we must first define the term "metal." The basic chemical elements are divided into metals and nonmetals; however, there is no sharp dividing line between the two groups. A metal may be defined as a chemical element that possesses metallic luster and which, in electrolysis, carries a positive charge and is liberated at the cathode. Most nonmetallic elements do not possess metallic luster, and in electrolysis the nonmetals carry negative charges and are liberated at the anode. Of all the natural chemical elements, about 70 are metals and, of these, about 39 are used commercially.

b. An alloy is a metallic substance, but it is not a single chemical element. An alloy is formed by the union or mixture of two or more metals and, in some cases, it may consist of one or more metals and a nonmetal. Examples of alloys are iron and carbon forming steel and copper and zinc forming brass.

c. The distinguishing characteristics or qualities that are used to describe a substance are known as the physical properties. Those special physical properties which describe the behavior of a metal when subjected to particular types of mechanical usage are called mechanical properties. When studying the properties of metals and alloys that are related to this lesson, the mechanical properties are of chief concern and will therefore receive greater coverage. Additional physical properties include electrical conductivity, heat conductivity, crystal structure, and magnetic properties.

d. The particular characteristics which are of interest to the large industries and the US Army are cost, strength, toughness, resistance to corrosion, machinability, specific gravity, resistance to fatigue, resistance to creep, and strength combined with resistance to oxidation at high temperatures.

4. STRENGTH.

a. The strength of a material is the property of resistance to external loads or stresses while not causing structural damage. Ultimate strength is the unit stress, measured in pounds per square inch, developed in the material by the maximum slowly applied load that the material can resist without rupturing in a tensile test.

b. Tensile strength is the ability of a metal to resist being pulled apart by opposing forces acting in a straight line (fig 1). It is expressed as the number of pounds of force required to pull apart a bar of material 1 inch wide and 1 inch thick. The tensile test is the one most often used to measure the strengths of various metals.

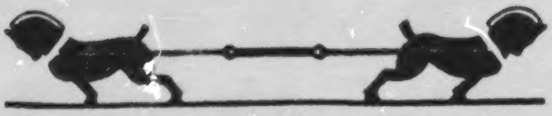


Figure 1.

c. Shear strength is the ability of a metal to resist being fractured by opposing forces not acting in a straight line (fig 2).

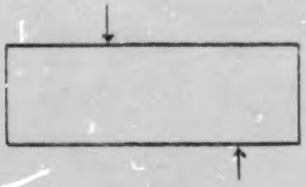


Figure 2.

d. Compressive strength is the ability of a metal to withstand pressure acting on a given plane (fig 3).

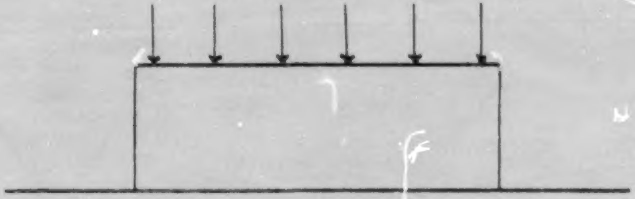


Figure 3.

e. The strength of metals and alloys depends upon two factors: the strength of the crystals of which the metals are constructed and the tenacity of adherence between these crystals. The strongest substance known is tungsten-molybdenum; titanium and nickel follow in order of strength of commercially pure metals. Pure iron is much weaker, but when alloyed with carbon to make steel it may then become stronger than any of the pure metals except tungsten.

5. **ELASTICITY.** Any material that is subjected to an external load is distorted or strained. Elastically stressed materials return to their original dimensions when the load is released, providing that the load is not too great. This distortion or deformation is in proportion to the amount of the load up to a certain point. If the load is too great, the material is permanently deformed, and when the load is further increased the material will break. The property of regaining the original dimensions upon removal of the external load is known as elasticity (fig 4).

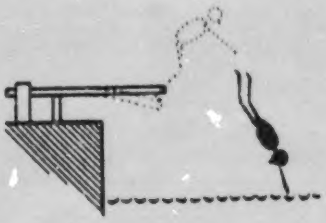


Figure 4.

6. STRESS AND STRAIN.

a. A stress is the force within a body which resists deformation due to an externally applied load. If this load acts upon a surface of unit area, it is called a unit force and the stress resisting it is a unit stress. Speaking quantitatively then, stress is the force per unit area. In the United States stress is expressed in pounds per square inch, while in England long tons per square inch is commonly used, and on the European continent it is kilograms per square millimeter.

b. When an external force acts upon an elastic material, the material is deformed and the deformation is in proportion to the load. This distortion or deformation is strain. The unit strain is measured in the United States in inches per foot and is thereby considered to be a ratio of distances or lengths.

7. **MODULUS OF ELASTICITY.** The modulus of elasticity expresses the stiffness of a material. For steel and most metals, this is a constant property and is affected very little by heat treatment, hot or cold working, or the actual ultimate strength of the metal.

8. **DUCTILITY.** Ductility is the capacity of a metal to be permanently deformed in tension without breaking. Specifically, the term denotes the capacity to be drawn from a larger to a smaller diameter of wire. This type of operation involves both elongation and reduction of area (fig 5).

9. **TOUGHNESS.** Toughness has been defined by some metallurgists as "the property of absorbing considerable energy before fracture" and, therefore, involves both ductility and strength. It is a measure of the total energy absorbing capacity of the material, including the energy of both elastic and plastic deformation under a gradually applied load. Generally speaking, toughness implies both strength and plasticity. Thus, a very easily deformed substance of low strength would not be considered tough, nor would a material of high strength, but with little plasticity, such as hardened tool steel. The true tough metal is one that will rapidly distribute within itself both the stress and resulting strain caused by a rapidly applied load.

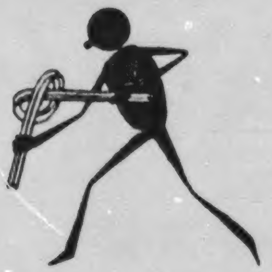


Figure 5.

10. **RESILIENCE.** Work must be expended in deforming a metal both elastically and plastically. Work expended in the elastic deformation is stored up as potential energy. When the load on an elastic substance is removed and it returns to its original dimensions, the stored energy can do work. This elastic energy is the resilience of the material. Examples of this type of action are illustrated by the energy recoverable from a clock spring or from a fishing rod when casting.

11. **MALLEABILITY.** Malleability is the property of a metal which permits permanent deformation by compression without rupture. Specifically, it means the capacity to be rolled or hammered into thin sheets. The property of malleability is similar to but not the same as that of ductility, and different metals do not possess the two properties in the same degree. Lead and tin are relatively high in order of malleability; however, they lack the necessary tensile strength to be drawn into fine wire. Most metals have increased malleability and ductility at higher temperatures. For example, iron and nickel are very malleable at a bright-red heat (fig 6).

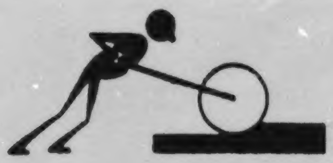


Figure 6.

12. **BRITTLENESS.** The term "brittleness" implies sudden failure. It is the property of breaking without warning; that is, without visible permanent deformation. It is the reverse of toughness in the sense that a brittle piece of metal has little resistance to rupture after it reaches its elastic limit. Brittleness can be said to be the opposite of ductility in the sense that it involves rupture with very little deformation. In many cases, hard metals are brittle; however, the terms should not be confused or used synonymously.

13. **FATIGUE.** When metal is subjected to frequent repetitions of a stress, it will ultimately rupture and fail, even though the stress may not be sufficient to produce permanent deformation if continuously applied for a relatively brief time. Such a repetition of stress may occur, for example, in the shank of a rock drill. Alternation of stress will produce failure more rapidly than repetition of stress. Alternations of stress mean the alternate tension and compression in any fiber. This is exemplified in stresses on the outer fibers of a rotating shaft which has been drawn out of alinement by a pulley belt. The definition of fatigue can be summarized by saying that it is the failure of metals and alloys that have had repeated or alternating stresses which were too small to produce a permanent deformation when applied statically.

14. CORROSION FATIGUE.

a. Failure by corrosion fatigue is a fatigue failure in which corrosion has lowered the endurance limit by the formation of pits that act as centers for the development of fatigue cracks. Moreover, when any protective film that has been placed on the metal is broken by the fatigue stresses, corrosion spreads through the cracks in the film and produces pits which act as stress raisers.

b. If a metal member exposed to fatigue is also exposed to corrosive agencies, such as a damp atmosphere or oil that has not been freed from acid, the stress necessary to cause failure is lowered. It is interesting to note that the unit stress of an extremely strong heat-treated alloy steel that is subject to corrosion fatigue will be no greater than that of a relatively weak structural steel. The importance of protecting the surfaces of fatigue members against corrosion by galvanizing, plating, etc, if and when possible, is obvious.

15. HARDNESS.

a. The quality of hardness is a complex one which detailed study has shown to be a combination of a number of physical properties. It is most often defined in terms of the method used for its measurement and usually means the resistance of a substance to indentation. Hardness may also be defined in terms of resistance to scratching and, thus, is related to wear resistance. The word "hardness" is sometimes used to refer to the stiffness or temper of wrought products because the indentation hardness of a metal is closely related to its tensile strength. The cutting characteristic of a metal when used as a tool is sometimes called its hardness, but reflections will show that these various indications of hardness are not the same.

b. In engineering practice, the resistance of a metal to penetration by a hard indenting tool is generally accepted as defining the hardness property.

SECTION III. HARDNESS TESTERS

16. **BRINELL HARDNESS TEST.** One of the more common methods of measuring the hardness of a metal is to determine its resistance to the penetration of a nondeformable ball or cone. This is done by determining the depth to which such a ball or cone will sink into a metal under a given load. The Brinell hardness test is made by forcing a hardened steel ball into the test material by the weight of a known load. The ball is usually 10 millimeters in diameter and has an applied load of 500 kilograms for soft materials such as copper and brass, and 3,000 kilograms for materials such as iron and steel. Once the load has been applied, the diameter of the resulting impression is measured with a small microscope. The hardness is reported as the load divided by the area of the impression. These figures are then composed with a Hardness Conversion Table and the resulting hardness of annealed copper is about 40, of annealed tool steel about 200, and of hardened tool steel about 650.

17. VICKERS HARDNESS TEST.

a. The Vickers hardness testing method is very similar to the Brinell method. The penetrator used in the Vickers machine is a diamond pyramid rather than the round steel ball of the Brinell. The impression made by this penetrator is a dark square on a light background. This type of impression is easier to measure than the circular impression. Another advantage lies in the fact that the diamond point does not deform as is possible with the steel ball.

b. When performing the Vickers test, a predetermined load is applied to the specimen. After removing the load, the impression is measured and the ratio of the impressed load to the area of the resulting impression gives the hardness number. The actual operation of applying and removing the load is controlled automatically. It has been found that several loadings will give practically identical numbers on uniform material. The Vickers tester is very precise and very adaptable for testing the softest and hardest materials under varying loads. The primary disadvantage with this testing device is its high cost and its limited capacity for testing.

18. ROCKWELL HARDNESS TESTER.

a. This type of test measures the resistance to penetration similarly to the Brinell test; however, the depth of impression is measured instead of the diameter and the hardness is indicated directly on the scale attached to the machine. The scale is basically a depth gage that has been graduated in special units. When testing soft materials, a 1/16-inch steel ball with a 100-kilogram load is used and the hardness is read on the correct scale. When testing hard materials, a diamond cone is used with a 150-kilogram load. The hardness is again read directly from the proper scale. The advantages of the Rockwell tester are that the test can be made quickly, that only a small mark is left on the sample, and that very hard materials can be tested with the diamond cone.

b. The Rockwell superficial hardness tester employs a light load, which causes very little penetration of the diamond cone. The superficial hardness tester does not differ in principle from the standard machine. The hardness number is based on the additional depth to which a test point penetrates the material after an additional load has been applied. The initial load is 3 kilograms while the additional or major loads vary between 15, 30, or 45 kilograms. The amount of the major load is dependent upon the thickness of the hard surface. This machine is very useful in testing exceptionally high surface hardness, such as case-hardened or nitrided surfaces.

19. **SHORE SCLEROSCOPE.** With this process, the hardness is measured by the height of rebound of a diamond-pointed hammer after it has been dropped on the sample. The harder the material used, the greater the rebound. The height of the rebound is recorded on a gage. The scleroscope can be used for large sections, it is portable, and the indentations made by the test are very slight. The amount of rebound is more a factor of the elastic limit of the specimen than of its tensile strength. Due to the machine being portable, it can be transported to the work and tests can be performed on specimens that are too large to be conveniently taken to other types of machines.

20. **MONOTRON.** The basic difference between this machine and other testing machines is that the depth of impression is kept constant and the readings of pressure are the basis for the degree of hardness. There are two dials at the top of the machine which allow the operator to read the depth of impression and the pressure applied. Increased pressure is applied until the penetrator sinks to the standard depth of 9/5000 inch. One advantage of this system being based on a constant depth of impression is that the same amount of cold work is performed regardless of whether the material tested is extremely hard or comparatively soft. Due to this advantage, a wider range of materials can be tested without working any change in the penetrator or the methods of the test.

SECTION IV. IDENTIFICATION OF METALS

21. INTRODUCTION. The ability to identify different types of metals is a necessity for anyone working in a construction or repair shop. The individual must be able to properly identify the types of metals so that he can apply the proper work procedures. There are simple tests that can be performed in the shop to identify metals. Since the ability to judge can be developed only through personal experience, the student should practice these tests with known metal until he becomes familiar with the reactions of each metal to each type of test.

22. SPARK TEST.

a. When the exact type of material is unknown, a spark test may be used to determine its identity. This is revealed by a study of the sparks formed when the material is held against a high-speed grinding wheel. This type of test is useful when a fast, nondestructive method of identification is needed.

b. When any form of iron or steel is held against a grinding wheel, small particles are released from the metal and thrown into the air. These particles are heated to a red or yellow heat. After contact with the oxygen in the air, the particles oxidize or burn. If an element such as carbon is present, rapid burning occurs, resulting in the bursting of the particle. The various forms of iron and steel produce sparks that vary in length, shape, and color.

c. The grinding wheel should be rotated to give a peripheral speed of 4,000 feet per minute. The wheel should also be hard enough to wear for a reasonable length of time and yet be soft enough to retain a free-cutting edge. All tests should be performed in well diffused daylight against an ordinary background. The use of standard samples of materials, whose compositions are known, for purposes of comparing their sparks with the test sample is recommended.

23. FRACTURE TEST. A fracture test is made simply by notching a specimen and then breaking it. Although there are no concrete values of the properties of a metal obtained from this test, many metals can be quickly identified by examining the surface of the break or by studying the chips produced with a hammer and chisel. The fracture test is probably the oldest of the methods used in the inspection and testing of metals.

24. APPEARANCE TEST.

a. This test, as the name implies, is based on the general appearance of the metal, which includes such general features as the color and overall appearance of machined and unmachined surfaces. It is obvious that this is not an extremely accurate method; however, the experienced metalworker can make a reasonable good determination based on experience and the above mentioned characteristics.

b. Another type of appearance test is based upon the action of the metal when subjected to heat. When this heat is applied, the various metals may be identified by studying the rate of melting, appearance of the molten metal and slag, and the changes in color during the heating process.

25. SAE STEELS.

a. One of the most widely known and generally used numbering systems for steel specifications and compositions is the one established by the Society of Automotive Engineers (SAE). The specifications were originally intended for use in the automotive industry; however, their use has spread into all industries where steels and alloy steels are being used.

14

b. A numeral index system is used to identify the compositions of the SAE steels. By using this procedure, it is possible to use numerals on shop drawings and blueprints that partially describe the composition of the material referred to.

c. To provide a better understanding of the SAE system, assume that a shop drawing indicates the use of 2340 steel. The first digit indicates the type to which the steel belongs, in this instance a nickel steel. In the case of the simple alloy steels, the second digit generally indicates the approximate percentage of the predominant alloying element (3 percent nickel). Usually, the last two or three digits indicate the average carbon content in points, or hundredths of 1 percent (0.40 hundredths of 1 percent carbon). From this explanation it can be seen that a 2340 designation indicates a nickel steel of approximately 3 percent nickel and 0.40 hundredths of percent carbon.

d. The basic numerals for the various types of SAE stee[illegible]re as follows:

Type of Steel	Numerals and Digits
Carbon steel	1XXX
Plain carbon	10XX
Free cutting (screw stock)	11XX
Manganese steels	13XX
Nickel steels	2XXX
3.50% nickel	23XX
5.00% nickel	25XX
Nickel-chromium steels	3XXX
1.25% nickel, 0.60% chromium	31XX
1.75% nickel, 1.00% chromium	32XX
3.50% nickel, 1.50% chromium	33XX
Corrosion- and heat-resisting	30XX
Molybdenum steels	4XXX
Carbon - molybdenum	40XX
Chromium - molybdenum	41XX
Chromium - nickel - molybdenum	43XX
Nickel - molybdenum	46XX & 48XX
Chromium steels	5XXX
Low chromium	51XX
Medium chromium	52XXX
Corrosion- and heat-resisting	51XXX
Chromium - vanandium steels	6XXX
1% chromium	61XX
Silicon - manganese steels	9XXX
2% silicon	92XX

SECTION V. PRODUCING IRON AND STEEL

2[illegible]. INTRODUCTION The terms "iron," "cast iron," and "steel" refer to a metal in which the basic element (iron (FC)) is the major element. These are, however, very loose terms and refer to a general type of alloy. When speaking of the commercial forms of iron such terms as "pig iron," "gray cast iron," or "wrought iron" should be used. Each of these terms represent some commercial form of the element iron, and each form may occur in many variations of chemical composition which may influence the particular functions within each class. It would, therefore, be helpful to have some basic understanding as to what these general terms mean and how the basic materials are produced.

27. IRON AND STEEL.

a. Wrought iron. This is the oldest form of iron made by man. Originally, it was produced by the reduction of metal ore to wrought iron in a forge fire. The reduction process resulted in a very impure product which required further refining. The refining consisted of hammering or shaping to the form in which it was to be used. Wrought iron is a metal that contains high purity iron and iron silicate. It is very low in carbon, with the iron silicate or slag being distributed throughout the base metal in fibers. These fibers give the material a woody or stringy appearance when broken.

b. Cast iron. Cast iron is basically an alloy whose chief elements are iron, silicon, and carbon. The material is available with a wide range of properties. There have been specifications established which provide for classes of cast iron ranging from 20,000 to 80,000 pounds per square inch minimum tensile strength. Each particular class has its own characteristics and, within each class, controls and modification may be desirable to adapt it to the particular design and condition of service contemplated. Pig iron, gray cast iron, white cast iron, chilled cast iron, and malleable cast iron, are all referred to as cast iron. This is due primarily to the fact that these forms of iron are not plastic enough, even when hot, to be forgeable. They are, therefore, always produced commercially by a process of melting and casting into shape. The commercial form of each of these metals is a cast shape.

c. Steel.

(1) This material, often considered as the master metal, is available in large quantities in both wrought and cast form. Due to its plasticity, steel may be worked at room temperature or at elevated temperatures. It is possible by varying the carbon content and by proper heat treatments to alter the properties from a very soft, workable steel of the type used in pressed metal parts, wire, and similar materials to a hard strong steel suitable for use in tool, machinery, and armor where great strength and hardness are necessary.

(2) Steel is basically an alloy of iron and carbon. The carbon content in the more common types of steel ranges from approximately 0.08 to 1.40 percent. The most important single factor governing the properties and uses of steel is the percentage of carbon. Steel was originally made by the process of adding carbon to wrought iron when it was in the solid state. Today, however, the carbon is added to the steel when it is in the molten state.

28. BLAST FURNACE.

a. The blast furnace is used to extract iron from ore (fig 7). The iron, as obtained from the furnace, may be remelted and cast into many different shapes and sizes. It may also be refined into steel or wrought iron. Our present day blast furnaces are built to produce very large quantities of iron each day and, due to the nature of the process, they must be kept in continuous operation.

b. Ore is reduced to metal in the blast furnace by means of coke charged with the ore. The impurities are fluxed or slagged by means of limestone. The ore, coke, and limestone are conveyed from the ground to the top of the furnace by means of skip cars mounted on rails. The materials are carefully weighed in order that they may be added in the proper proportions. These proportions are dependent upon the particular furnace and the grade of ore used. The charge is dropped into the furnace by lowering the top bell and

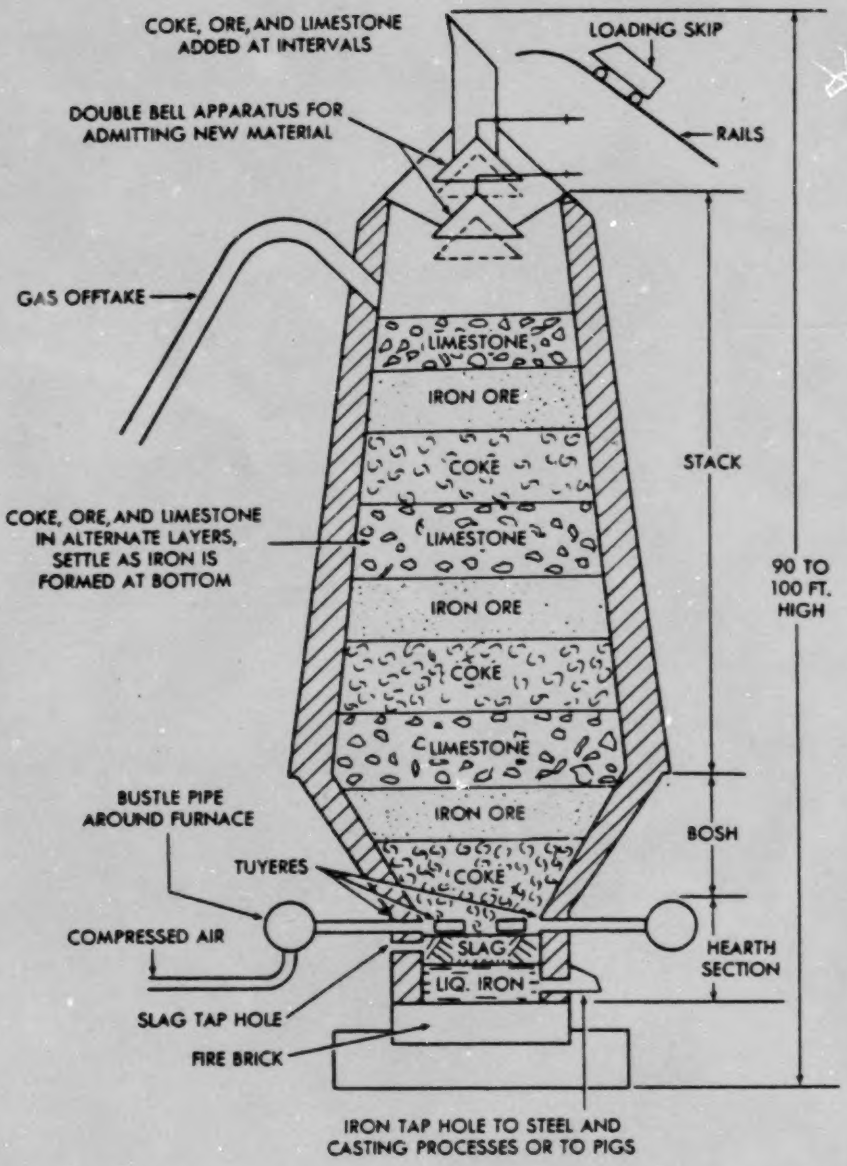

COKE, ORE, AND LIMESTONE ADDED AT INTERVALS
LOADING SKIP
DOUBLE BELL APPARATUS FOR ADMITTING NEW MATERIAL
RAILS
GAS OFFTAKE
LIMESTONE
IRON ORE
COKE
STACK
COKE, ORE, AND LIMESTONE IN ALTERNATE LAYERS, SETTLE AS IRON IS FORMED AT BOTTOM
LIMESTONE
90 TO 100 FT. HIGH
IRON ORE
COKE
LIMESTONE
BUSTLE PIPE AROUND FURNACE
IRON ORE
BOSH
TUYERES
COKE
COMPRESSED AIR
SLAG
HEARTH SECTION
LIQ. IRON
SLAG TAP HOLE
FIRE BRICK
IRON TAP HOLE TO STEEL AND CASTING PROCESSES OR TO PIGS

Figure 7. Blast furnace.

letting it fall down to the lower bell. The top bell is then closed and the lower bell opened allowing the charge to fall into the furnace. The use of these two bells prevents gases and flame from being blown into the air from the top of the furnace whenever it is charged.

c. Hot air is blown into the furnace through the tuyeres or nozzles near the bottom of the furnace. Exhaust gas is taken from near the top of the furnace and then through a dust catcher and washer. This gas contains nitrogen, carbon dioxide, and carbon monoxide. Since the carbon monoxide is combustible, it is burned to help furnish the necessary power and heat. About a third of this gas is used in heating the stoves which heats the air as it is blown into the furnace. These stoves consist of a steel shell containing several small brick flues. The burning gas heats the bricks. Once the bricks are sufficiently hot, the gas is turned off and the air from the furnace is blown through.

d. As the iron and slag are formed, they drop to the hearth section at the bottom of the furnace. The iron is heavier than the slag, therefore it settles to the bottom while the slag floats on the top. There are two holes near the bottom of the furnace. The lower hole, or iron notch from which the iron is tapped, is closed by shooting clay balls into it from an airgun. The lower hole, or cinder notch from which the slag is tapped, closes by means of a metal plug. The iron is tapped every 4 or 5 hours by digging out the clay plug. It is usual for the slag to be tapped two or three times between each iron tapping. Many of the impurities found in the ore are collected and removed with the molten limestone in the form of slag.

e. The iron runs from the furnace into troughs which convey it to a ladle. The troughs are equipped with a skimmer which diverts the slag to a dump car. The iron in the ladle is then cast into pigs or is taken, while still in the molten state, to the steel-making furnaces. The slag is sometimes used in the manufacture of cement; however, in most cases, it is simply dumped.

29. OPEN-HEARTH PROCESS.

a. The basic open-hearth process is the least expensive method of eliminating, or partly eliminating, the different common impurities in pig iron. It is customary for a part of the charge to consist of steel scrap because this is not only lower in impurities than pig iron, but it can usually be bought at a lower price, and the "return scrap" from the finishing mills is utilized in amounts usually equal to the "bought scrap." Scrap makes the process shorter and less expensive. In normal times it averages about 50 percent by weight of the charge, but this depends greatly on the availability of both scrap and pig iron. Scrap cast iron can be used in place of a part of the pig iron. Whenever possible, the pig iron is brought to the open-hearth furnace in a molten condition. The furnace is lined with magnesite and repaired with dolomite. They are fired with preheated gas, burned with preheated air, or else with oil or tar. Their general form and operation is shown in figure 8.

b. The four regenerative chambers below the furnace (fig 8) are filled with a checkerwork of brick around which the gas and air may pass. Before the furnace is started, these bricks are heated by means of wood fires. The gas enters the furnace through the inner regenerative chamber on one side, and the air enters through the outer one on the same side. They meet and unite, passing through the furnace and then passing to the chimney through the two regenerative chambers at the opposite end. In this way, the brickwork in the outgoing chambers is heated still hotter by the waste heat of the furnace. The current of gas, air, and products of combustion is changed every 15 minutes, whereby all four regenerators are always kept hot. The gas and air enter the furnace in a highly preheated condition, giving a higher temperature of combustion, while the products of combustion go to the chimney carrying relatively little heat, and thus fuel economy is secured. If oil or tar is used, it is introduced through a water-cooled burner which enters the furnace through the end wall.

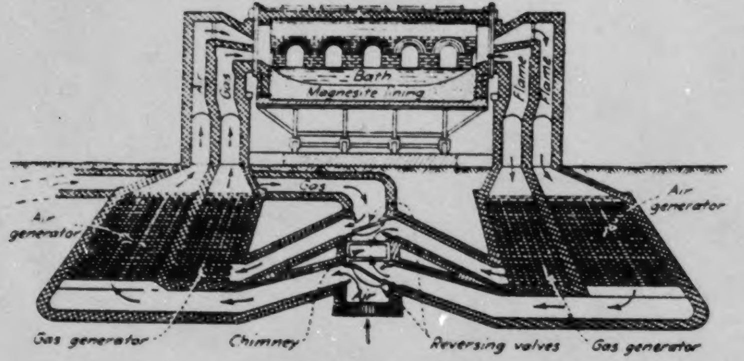


Figure 8. Diagram of regenerative open-hearth furnace.

c. The total time used for the treatment of a charge depends on the purity of the materials charged and the exact mode of operation. The process is a very slow one as compared with the Bessemer, but the slowness permits careful control. Toward the end of the heat, samples are taken and analyzed and the results are reported to the operator so that he may adjust the bath to the proper composition before casting. The carbon is very quickly and accurately determined at the furnace by means of a magnetic analyzer known as a "carbometer."

30. BESSEMER PROCESS.

a. The Bessemer process as operated in America is an acid process. This is the reason that it is no longer the predominant purification process. Pig iron, low in phosphorus, is becoming more costly on account of the exhaustion of our low-phosphorus iron ores. The Bessemer furnace is a pear-shaped converter lined with silica brick (fig 9). It is not adapted to melting iron, but molten pig iron is brought to it and poured in to the amount of about 25 tons per charge. Then the converter is turned into an upright position and a blast of cold air is blown through it. In about 7 minutes the oxygen of the air has oxidized all the silicon and manganese in the iron. This produces a great deal of heat, which increases the temperature of the bath. The carbon then begins to burn to CO, which escapes at the mouth of the converter and there burns to CO_2, with a long and brilliant flame. In a few minutes, the carbon is also oxidized and removed and all the impurities are now eliminated except phosphorous and sulfur. Commercial oxygen has been used to enrich the blast blown into the Bessemer converter, with a resulting higher temperature and shorter time. The higher temperatures reached permit scrap to be used.

b. The rapid and simple Bessemer purification process was the first to give large quantities of cheap steel to the world; it inaugurated the Age of Steel in civilization. Its disadvantages were that it left the metal with all its original phosphorus and sulfur and also with oxygen in it. Further, it is higher in nitrogen than are steels from the other processes. The chief use of Bessemer steel is for free-machining screwstock, for which it is unexcelled. Sometimes sulfur is intentionally added to basic open-hearth steel to make it free-machining, and recent attempts have been made to add nitrogen as well. Bessemer steel is used for small structural shapes, small railroad rails, and some wire, pipe, and uses where highest quality is not demanded. The process is also used as an adjunct to the basic open hearth in the so-called "duplex process."

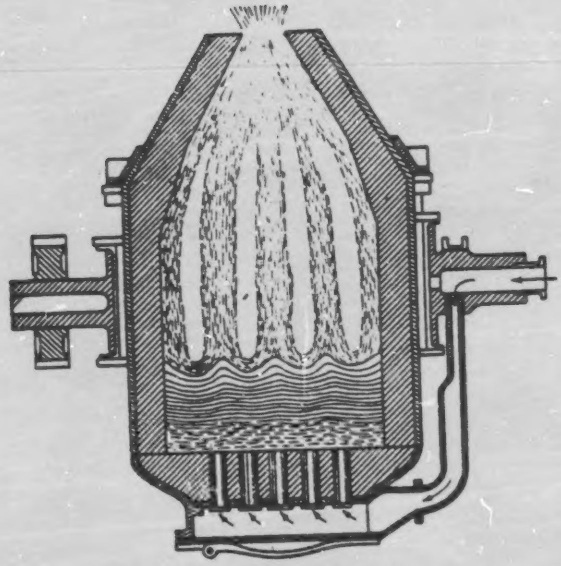


Figure 9. Section through Bessemer converter while blowing.

31. DUPLEX PROCESS. Liquid pig iron from the blast furnace and liquid purified metal from the Bessemer converter are poured into a basic open-hearth furnace. This eliminates the time and cost of melting in the open hearth, and requires only that the bath be purified of phosphorus and some sulfur and then brought to the requisite temperature for tapping.

32. ELECTRIC PROCESS.

a. Steel is often produced with the aid of electrical energy, which has no other function than to provide the necessary heat (fig 10). The two chief technical advantages are:

(1) The possibility of attaining any temperature in reason.

(2) The possibility of working in a nonoxidizing atmosphere.

b. Heat from electrical energy is costly, but the very high temperature obtainable makes it possible to perform certain operations which can be performed only in an unsatisfactory manner in combustion furnaces, such as the open hearth. The outstanding example of this is the possibility of desulfurizing metal through the use of a slag so rich in lime that it would not be fusible in other types of furnace. A slag containing calcium carbide is one of the best desulfurizers and deoxidizers for steel that has been developed. Calcium carbide is formed at the temperature reached in the electric-arc furnace when lime and carbon are in contact. It can exist only in high-lime slags in a nonoxidizing atmosphere.

c. The induction principle is also used for the heating of electric melting furnaces. A thorough stirring of the charge and the protection of the charge from the atmosphere are two outstanding characteristics of this type of furnace. The melting of alloy steel scrap with highly oxidizable components, such as tungsten, is satisfactorily accomplished. Vacuum melting is sometimes practiced in furnaces of less than 2 tons' capacity.

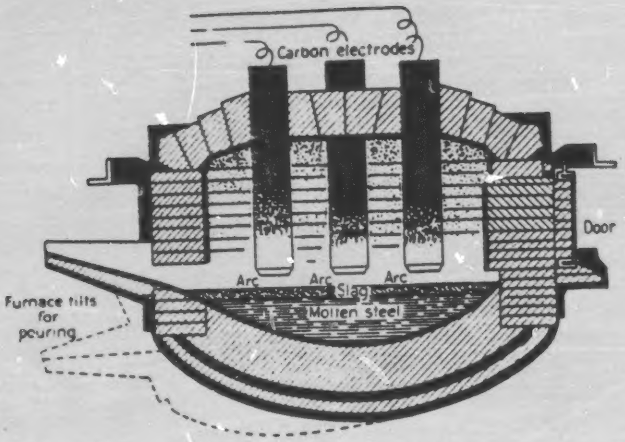


Figure 10. Electric arc furnace.

33. ELECTRIC SUPERREFINING. The cheapest electric process is the superrefining of basic open-hearth steel in an arc furnace. In this process the impurities are reduced to the lowest possible point in the basic open-hearth furnace, and the melted metal is then poured into the electric furnace in which it is superrefined; i.e., it is purified to any desired point in sulfur content and to almost any desired point in oxygen and solid inclusions. No oxidizing slag is used, but the metal is maintained in a fluid condition at a fairly high temperature under a slag rich in lime and reducing in character by virtue of its content of carbon, which is charged in the form of crushed coke. It is of importance that the metal should lie quietly in the furnace under deoxidizing conditions for a considerable length of time, in order that the suspended particles, which are often almost microscopic in size, can rise by gravity and clarify the bath. The stream of metal must be protected as much as possible from surface oxidation during the pouring from the furnace into the ladle and from the ladle into the mold in which it solidifies; and, finally, the metal should be protected from subsequent entrainment of particles such as would occur if the slag were churned up with the metal, or if elements like silicon, manganese, etc, were added to the metal in the ladle. In the latter case, particles of oxidized silicon, manganese, etc, are likely to be produced and then become entrapped in the solid metal.

34. CRUCIBLE PROCESS.

a. High-grade tool steels and some alloy steels are still made by the crucible process, although the electric furnace is now capable of making steel equal in quality to crucible steel. In the crucible process, wrought iron and/or good scrap, together with a small amount of high purity pig iron, ferromanganese, the necessary alloying metals, and slagging materials are placed in a clay or clay-graphite crucible and melted in a gas or coke-fired furnace. After the charge is entirely molten and sufficient time is allowed for the gases and impurities to rise to the surface, the crucible is withdrawn. A cold iron bar is then used to remove the slag. The remaining steel is poured into an ingot which is subsequently forged to the desired shape.

b. The crucible process differs from other steelmaking in that there is little or no refining included in the entire operation. From this, it can be seen that the purity of the finished metal is almost entirely dependent upon the purity of the materials charged. The primary advantage of the process is that it removes most of the impurities, including oxygen and entangled particles.

SECTION VI. FERROUS METALS

35. CAST IRON (GRAY, WHITE, AND MALLEABLE).

a. History. Cast iron, developed in the latter part of the 18th century, is a man-made alloy of iron and carbon (graphite) plus silicon. It is generally produced in a cupola furnace that is a vertical, cylindrical type of melting furnace consisting of a steel shell lined with firebrick. Basic ingredients used in the manufacture of cast iron are coke, limestone, pig iron, steel, and iron scrap. This charge is melted directly in the cupola and is poured into molds where solidification takes place. These molds are produced from an original pattern and conform to the design of any desired part. Pig iron, a purer form of iron, is reduced from iron ore in a blast furnace. Cast iron is nothing more than basic carbon steel with more carbon added along with silicon. A portion of the carbon exists as free carbon or graphite. Total carbon content is more than 1.7 percent and less than 4.5 percent. Malleable iron is a tougher form of cast iron than gray iron. Cast iron products are made throughout the world.

b. Uses. Cast iron is used for water pipes, machine tool castings, transmission housings, engine blocks, pistons, stove castings, etc.

c. Capabilities. Cast iron is commonly brazed or bronze welded, but it can be gas and arc welded, hardened, or machined.

d. Limitations. Cast iron must be preheated prior to welding; it cannot be cold worked.

e. Properties.

(1) Brinell hardness No - 150 to 220 (unalloyed).

(2) Brinell hardness No - 300 to 600 (alloyed).

(3) Tensile strength - 25,000 to 50,000 PSI (unalloyed).

(4) Tensile strength - 50,000 to 100,000 PSI (alloyed).

(5) Specific gravity - 7.6.

(6) Modulus of elasticity - 12,000,000 to 29,000,000 PSI.

(7) High compressive strength - four times the tensile strength.

(8) High rigidity.

(9) Good wear resistance.

(10) Fair corrosion resistance.

f. Gray cast iron. If molten pig iron is permitted to cool quite slowly, the chemical compound of iron and carbon breaks up to a certain extent, and much of the carbon separates out as tiny flakes of graphite scattered throughout the metal. This graphitic carbon, as it is called to distinguish it from combined carbon, causes the gray appearance of the fracture which characterizes ordinary gray cast iron. Since graphite is an excellent lubricant, and the metal is filled with tiny flaky cleavages, it is not difficult to understand why gray cast iron is so easy to machine and why it cannot withstand a heavy shock. Gray cast iron consists of from 90 to 94 percent metallic iron with varying proportions of carbon, manganese, phosphorus, sulfur, and silicon. Special high-strength grades of this metal contain 0.75 to 1.5 percent nickel and 0.25 to 0.5 percent chromium or 0.25 to 1.25 percent molybdenum. Commerical gray iron has 2.5 to 4.5 percent carbon. Of this quantity, about 1 percent of the carbon is combined with the iron, while about 2.75 percent remains in the free or graphitic state. In the production of gray cast iron, the silicon content is usually increased, since this facilitates the formation of graphitic carbon. The combined carbon (iron carbide), which is a small percentage of the total carbon present in cast iron, is known as cementite. In general, the more free carbon (graphitic carbon) present in cast iron the lower the combined carbon content and the softer the iron.

(1) Appearance. Gray cast iron castings present a characteristic appearance. The unmachined surface is very dull gray in color and may be somewhat roughened by the sand mold used in casting the part. Cast iron castings are rarely machined all over. Unmachined castings may be ground in places to remove rough edges.

(2) Fracture. Nick a corner all around with a chisel or hacksaw and strike the corner with a sharp blow of the hammer. The dark gray color of the broken surface is caused by fine black specks of carbon present in the form of graphite. Cast iron breaks short when fractured. Small brittle chips made with a chisel break off as soon as they are formed.

(3) Grinding wheel test. A small volume of dull red sparks that follow a straight line form close to the wheel when this metal is given the grinding wheel test. These break up into many fine, repeated spurts that change to a straw color.

(4) Torch test. The torch test results in a puddle of molten metal that is quiet and has a jellylike consistency. When the torch flame is raised, the depression in the surface of the molten puddle disappears instantly. A heavy, tough film forms on the surface as it melts. The molten puddle takes time to solidify and gives off no sparks.

g. White cast iron. When gray cast iron is heated to the molten state, the carbon completely dissolves in the iron, probably combining chemically with it. If this molten metal is cooled quickly, the two elements remain in the combined state, and white cast iron is formed. The carbon in this type of iron measures generally from 2.5 to 4.5 percent by weight and is referred to as combined carbon. White cast iron is very hard and brittle, often impossible to machine, and has a silvery white fracture.

h. Malleable cast iron. Malleable cast iron is made by heating white cast iron to between 1,400° and 1,700° F for about 150 hours in boxes containing hematite ore or iron scale. This heating causes a portion of the combined carbon to change into the free or uncombined state. This free carbon separates out in a different manner from carbon in gray cast iron. It is called temper carbon. It exists in the form of small, somewhat rounded particles of carbon, which give malleable iron castings the ability to bend before breaking and to withstand shock loads better than gray cast iron. The castings have more properties like those of pure iron; namely, high strength, ductility, toughness, and ability to resist shock. Malleable cast iron can be brazed.

(1) Appearance. The surface of malleable cast iron is very much like cast iron but is generally free from sand. It is dull gray and somewhat lighter in color than cast iron.

(2) Fracture. When malleable cast iron is fractured, the central portion of the broken surface is dark gray with a bright, steellike band at the edges. The appearance of the fracture may best be described as a picture frame. When of good quality, malleable cast iron is much tougher than other cast irons and does not break short when nicked.

(3) Grinding wheel test. When malleable cast iron is ground, the outer, bright layer gives off bright sparks like steel. When the interior is reached, the sparks quickly change to a dull red color near the wheel. These sparks from the interior section are very much like those of cast iron; however, they are somewhat longer and are present in larger volume.

(4) Torch test. Molten malleable cast iron boils under the torch flame. After the flame has been withdrawn, the surface will be found full of blowholes. The melted parts are very hard and brittle, having, when fractured, the appearance of white cast iron. (They have been changed to white or chilled iron by melting and comparatively rapid cooling.) The outside, bright steellike band gives off sparks, but the center does not.

36. DIFFERENCE BETWEEN CAST IRONS AND STEELS.

a. All the various forms of cast iron, steel, and wrought iron consist of chemical compounds and mixtures of iron, carbon, and various other elements in small quantities. Whether the metal is classified as cast iron or one of the steels depends entirely upon the amount of carbon in it. The following table illustrates this principle:

Item	Approximate Percent of Carbon	Condition of Incorporated Carbon
Pig iron	4.0	Free and combined
White cast iron	3.5	Mostly combined
Gray cast iron	2.5 to 4.5	0.6 to 0.9 percent free 2.6 to 2.9 percent combined
Malleable cast iron	2.0 to 3.5	Free and combined
Tool steel	0.9 to 1.7	All combined
High-carbon steel	0.5 to 0.9	All combined
Medium-carbon steel	0.3 to 0.5	All combined
Cast steel	0.15 to 0.6	All combined
Low-carbon steel	up to 0.3	All combined

b. Cast iron differs from steel principally because its excess of carbon (exceeding 1.7 percent) is precipitated throughout the matrix as flakes of graphite, thereby causing most of the remaining carbon also to precipitate. These particles of graphite form the paths through which failures occur and are the reason why cast iron is brittle. By carefully controlling the silicon content and the rate of cooling of cast iron, it is possible to cause any definite amount of the carbon to precipitate as graphite or to remain combined as Fe_3C. Thus, we have white, gray, and malleable cast iron all produced from similar base metals.

37. WROUGHT IRON.

a. History. For centuries, the smelting of iron ore with a charcoal fire on a hearth was used to produce a carbon-free iron or wrought iron. Recently, other methods for producing wrought iron have been devised. They are mainly indirect methods; that is, ore is first reduced to pig iron which is then transformed to wrought iron. Until the production of modern steels began in 1860, wrought iron was the outstanding structural metal, the carbon content being less than 0.08 percent. Wrought iron is made from pig iron in a puddling furnace. The carbon and other elements present in pig iron are eliminated to leave almost pure iron. In the process of manufacture, some slag is mixed with iron to form a fibrous structure in which long stringers of slag, running lengthwise, are mixed with long threads of iron. Because of the presence of slag, wrought iron resists corrosion and oxidation. It can be easily welded by any method.

b. Uses. Wrought iron is used for architectural railings, farm implements, nails, barbed wire, chains, modern household furniture, etc.

c. Capabilities. Wrought iron can be gas and arc welded, machined, and hot and cold worked. It can also be plated.

d. Limitations. Wrought iron has low hardness and low fatigue strength.

e. Properties.

(1) Brinell hardness No - 105.

(2) Tensile strength - 35,000 PSI.

(3) Specific gravity - 7.7.

(4) Melting point - 2,750° F.

(5) Ductile.

(6) Corrosion resistant (limited).

f. Identification.

(1) Appearance. The appearance of wrought iron is the same as that of rolled, low-carbon steel.

(2) Fracture. Wrought iron has a fibrous structure due to threads of slag. As a result, it can be split in the direction in which the fibers run. The metal is soft and easily cut with a chisel. When bent, it is quite ductile. When nicked and bent, it acts like rolled steel; however, the break is very jagged. Wrought iron cannot be hardened by quenching from bright red heat.

(3) Grinding wheel test. When wrought iron is ground, straw-colored sparks form near the grinding wheel and change to white forked sparklers near the end of the stream.

(4) Torch test. Wrought iron melts quietly without sparking. It has a peculiar slag coating with white lines that are oily or greasy in appearance.

38. STEEL.

a. History. The early metalworker, having produced wrought iron, accidentally produced steel. Whenever a small piece of metallic iron was left in a bed of smoldering charcoal overnight, the solid iron would absorb enough carbon to increase its hardness and strength appreciably, especially after being dipped in water. Modern steel was first produced in the United States in 1860. Today, steels are produced in several different types of furnaces - Bessemer, open-hearth, electric-arc, and induction. Raw materials utilized include pig iron, iron ore, limestone, and scrap. A form of iron, steel contains less carbon than cast iron but considerably more than wrought iron. Carbon content is from 0.03 to 1.7 percent. Basic carbon steels are alloyed with other elements such as chromium and nickel to increase certain physical properties of the metal.

b. Uses. Steel is used to make nails, rivets, gears, structural steel, axles, desks, hoods, fenders, chisels, hammers, etc.

c. Capabilities. Steel can be machined, welded, and forged - all to varying degrees depending on the type of steel.

d. Limitations. Highly alloyed steels are difficult to fabricate.

e. Properties.

(1) Tensile strength.

(a) 45,000 PSI - low-carbon steel.

(b) 80,000 PSI - medium-carbon steel.

(c) 99,000 PSI - high-carbon steel.

(d) 150,000 PSI - alloyed steel.

(2) Modulus of elasticity - 30,000,000 PSI.

(3) Melting point - 2,800° F.

Note. - See Metals Handbook for complete listings.

f. Low-carbon steels (carbon content up to 30 points). These steels are soft and ductile and can be rolled, punched, sheared, and worked when either hot or cold. They are easily machined and can be readily welded by all methods. They do not harden to any appreciable amount when quenched from a high temperature.

(1) Appearance. The appearance of the steel depends upon the method of preparation rather than upon composition.

(a) Cast steel has a relatively rough, dark-gray surface, except where machined.

(b) Rolled steel has fine surface lines running in one direction.

(c) Forged steel is usually recognizable by its shape, hammer marks, or fins.

(2) Fracture. When low-carbon steels are fractured, the color is bright crystalline. They are tough when chipped or nicked.

(3) Grinding wheel test. The steel gives off sparks in long yellow-orange streaks, brighter than cast iron, that show some tendency to burst into white forked sparklers.

(4) Torch test. The steel gives off sparks when melted and solidifies almost instantly.

g. Medium-carbon steels (carbon content ranging from 30 to 50 points). These steels may be heat-treated after fabrication and used for general machining and forging of parts that require surface hardness and strength. They are manufactured in bar form and in the cold-rolled or the normalized and annealed condition. During welding, the weld zone will become hardened if cooled rapidly and must be stress-relieved after welding.

h. High-carbon steels (carbon content ranging from 50 to 90 points). These steels are used for the manufacture of drills, taps, dies, springs, and other machine tools and handtools that are heat-treated after fabrication to develop the hard structure necessary to withstand high shear stress and wear. They are manufactured in bar, sheet, and wire forms and in the annealed or normalized and annealed condition in order to be suitable for machining before heat treatment. These steels are difficult to weld because of the hardening effect of heat at the welded joint.

(1) Appearance. The unfinished surface of high-carbon steel is dark gray and similar to other steels. These steels are more expensive and work is usually done on them to produce a smoother surface finish.

(2) Fracture. High-carbon steels usually produce a very fine-grained fracture, whiter than low-carbon steels. Tool steel is harder and more brittle than plate steel or other low-carbon material. High-carbon steel can be hardened by heating to a good red and quenching in water. Low-carbon steel, wrought iron, and steel castings cannot be hardened.

(3) Grinding wheel test. High-carbon steel gives off a large volume of brilliant, yellow-orange sparklers.

(4) Torch test. Molten high-carbon steel is brighter than low-carbon steel and the melting surface has a cellular appearance. It sparks more freely than low-carbon (mild) steel and the sparks are whiter.

i. Tool steels (carbon content ranging from 90 to 170 points). These steels are used in the manufacture of chisels, shear blades, cutters, large taps, wood-turning tools, blacksmith's tools, razors, and other similar parts where high hardness is required to maintain a sharp cutting edge. They are relatively difficult to weld due to the high carbon content.

39. CAST STEEL. In general, welding is difficult on steel castings containing over 0.3 percent carbon and 0.2 percent silicon. Alloy steel castings containing nickel or molybdenum or combinations of these metals are readily welded if the carbon content is low. Those containing chromium or vanadium are more difficult to weld satisfactorily. Since manganese steel is nearly always used in the form of castings, it is also considered in this paragraph. Its high resistance to abrasion is its most valuable property.

a. Appearance. The surface of cast steel is brighter than cast or malleable iron and sometimes contains small, bubblelike depressions.

b. Fracture. The color of a fracture in cast steel is bright crystalline. This steel is tough and does not break short. Steel castings are tougher than malleable iron, and chips made with a chisel curl up more. Manganese steel, however, is so tough that it cannot be cut with a chisel nor can it be machined.

c. Grinding wheel test. The sparks created from cast steel are much brighter than those from cast iron. Manganese steel gives off characteristic sparks that explode, throwing off brilliant sparklers at right angles to the original path of the spark.

d. Torch test. When melted, cast steel sparks and solidifies quickly.

40. STEEL FORGINGS.

a. Appearance. The surface of steel forgings is smooth. Where the surface of drop forgings has not been finished, there will be evidence of the fin that results from the metal squeezing out between the two forging dies. This fin is ordinarily removed by the trimming dies, but enough of the sheared surface remains for identification. All forgings are covered with reddish-brown or black scale, unless they have been purposely cleaned.

b. Fracture. The color of a fracture in a steel forging varies from bright crystalline to silky gray. Chips are tough; and when the specimen is nicked, it is harder to break than cast steel and has a finer grain. Forgings may be of low- or high-carbon steel or of alloy steel. Tool steel is harder and more brittle than plate steel or other low-carbon material. The fracture is usually whiter and finer grained. Tool steel can be hardened by heating to a good red and then quenching in water. Low-carbon steel, wrought iron, and steel castings cannot be usefully hardened.

c. Grinding wheel test. The sparks given off are long, yellow-orange streamers and are typical steel sparks. Sparks from high-carbon steel (machinery and tool steel) are much brighter and lighter than those from low-carbon steel.

d. Torch test. Steel forgings spark when melted, and the sparks increase in number and brilliance as the carbon content becomes greater.

41. ALLOY STEELS. Alloy steels are frequently recognized by their use. There are many varieties of alloy steels used in the manufacture of Army equipment. Each of these is best identified by experience. They have greater strength and durability than other carbon steels, and a given strength is secured with less material weight. Their economical use depends upon proper heat treatment that is destroyed by a welding operation in the region of the weld. Manganese steel is a special alloy steel that is always used in the cast condition and has been discussed under cast steel. Nickel, chromium, vanadium, tungsten, molybdenum, and silicon are the most common elements used in alloy steels.

a. Appearance. Alloy steels appear the same as other drop-forged steels. Much alloy steel is machined all over.

b. Fracture. Generally, the alloy steels are very close grained; at times the fracture might be said to have a velvety appearance.

c. Grinding wheel tests. The various alloy steels produce characteristic sparks both in color and shape. With practice, many varieties of alloy steels can be recognized. Some of the more common alloys used in steel and their effects on the spark stream are as follows:

(1) Manganese. Steels containing this element produce a spark similar to a carbon spark. A moderate increase in manganese increases the volume of the spark stream and the intensity of the bursts. A steel containing more than the normal content of manganese will spark in a manner similar to a high-carbon steel with a low manganese content. For example, SAE 1055 spark is similar to that of SAE 1335.

(2) Nickel. In the amounts found in SAE steels, nickel can be recognized only when the carbon content is so low that the bursts are not too prominent. The nickel spark has a short, sharply defined dash of brilliant light just before the fork.

(3) Chromium. Steels containing 1 to 2 percent chromium have no outstanding features in the spark test. Chromium in large amounts shortens the spark stream length to one-half that of the same steel without chromium, but it does not appreciably affect the stream's brightness. Other elements shorten the stream to the same extent and also make it duller. An 18-percent chromium, 8-percent nickel, stainless steel produces a spark similar to that of wrought iron but only one-half as long. A steel containing 14 percent chromium and no nickel produces an abbreviated version of the low-carbon spark. An 18-percent chromium, 2-percent carbon, steel (chromium die steel) produces a spark similar to that of a carbon tool steel but one-third as long.

(4) Molybdenum. Steels containing this element produce a characteristic spark with a detached arrowhead similar to that of wrought iron. It can be seen even in fairly strong carbon bursts. Molybdenum alloy steels contain either nickel or chromium or both.

(5) Vanadium. Alloy steels containing vanadium produce sparks with a detached arrowhead at the end of the carrier line similar to those arising from molybdenum steels. This test is not a positive one for vanadium steels.

(6) Tungsten. This element is simplest to recognize. It imparts a dull red color to the spark stream near the wheel. It also shortens the spark stream and decreases the size of, or completely eliminates, the carbon burst. A tungsten steel containing about 10 percent tungsten causes short, curved, orange spear points at the end of the carrier lines. Still lower tungsten content causes small, white bursts to appear at the end of the spear point. Carrier lines may be anything from dull red to orange in color depending on the other elements present and providing the tungsten content is not too high.

(7) Molybdenum and other elements. When molybdenum and other elements are substituted for some of the tungsten in high-speed steel, the spark stream turns orange. Although other elements give off a red spark, there is enough difference in their characteristics to distinguish them from the tungsten spark.

d. Torch test. The action of an alloy steel in this test depends upon the nature of the alloy. Steels containing a considerable quantity of chromium produce a greenish-colored slag on the weld when cold.

42. SPECIAL STEELS.

a. Plate steel is used in the manufacture of built-up welded structures such as gun carriages. In using nickel steel plate, it has been found through several years of experience that commercial grades of low-alloy, structure steels of not over 0.25 percent carbon, and several containing no nickel at all, are more satisfactory from the welding standpoint than those with a maximum carbon content of 0.3 percent.

b. Such plate is normally used in the "as rolled" condition. Electric arc welding with a covered electrode may require preheating followed by a proper stress-relief heat treatment to produce a structure in which the welded joint has properties equal to those of the plate metal.

SECTION VII. NONFERROUS METALS

43. ALUMINUM (AL).

a. History. Aluminum, the most abundant metal in the earth's crust, was discovered in 1825, yet its commercial history covers only 60 years. The principal ore of aluminum, bauxite ($AL_2O_3.3H_2O$ and $AL_2O_3.H_2O$), is produced by the weathering of aluminum silicate rocks. Principal supplies of bauxite come from the United States (Arkansas), France, Dutch Guiana, Hungary, Italy, Russia, and Canada.

b. Uses. Aluminum is used as a deoxidizer and alloying agent in the manufacture of steel. Castings, pistons, torque converter pump housings, aircraft structures, kitchen utensils, railway cars, and transmission lines are being made of aluminum.

c. Capabilities. Aluminum can be cast-forged, machined, and welded.

d. Limitations. Direct metal contact of aluminum with copper and copper alloys should be avoided. Aluminum should also be used in low temperature applications.

e. Properties.

(1) Pure.

(a) Brinell hardness No - 17 to 27.

(b) Tensile strength - 6,000 to 16,000 PSI.

(c) Modulus of elasticity - 10,000,000 PSI.

(d) Specific gravity - 2.7.

(e) Melting point - 1,220° F.

(2) Alloy 24S.

(a) Brinell hardness No - 100 to 130.

(b) Tensile strength - 30,000 to 75,000 PSI.

(3) General.

(a) High electrical conductivity (60 percent that of copper, volume for volume).

(b) High strength/weight ratio at room temperatures.

(c) Fairly corrosion resistant.

f. Appearance. Aluminum is light gray to silver in color, very bright when polished, dull when oxidized, and light in weight. Rolled and sheet aluminum materials are usually pure metal. Castings are alloys of aluminum with other metals, usually zinc, copper, silicon, and sometimes iron and magnesium. Wrought aluminum alloys may contain chromium, silicon, magnesium, or manganese.

g. Fracture. A fracture in aluminum castings shows a bright crystalline structure. A fracture in rolled aluminum sections shows a smooth and bright structure.

h. Grinding wheel test. No sparks are given off from aluminum in this test.

i. Torch test. Aluminum does not show red before melting. It holds its shape until almost molten, then collapses suddenly. A heavy film of white oxide forms instantly on the molten surface.

44. CHROMIUM (Cr).

a. History. Chromium was first discovered in 1797. The chief ores of chromium are chromite ($Cr_2O_3 \cdot FeO$) and chrome ochre (Cr_2O_3).

b. Uses. Chromium is one of the most versatile and widely used alloys. It is used as an alloying agent in steel and cast iron (0.25 to 0.35 percent) and in nonferrous alloys of nickel, copper, aluminum, and cobalt. It is also used in electroplating for appearance and wear, in powder metallurgy, and to make X-ray targets, mirrors, and stainless steel.

c. Capabilities. Chromium can be welded, machined, and forged.

d. Limitations. Chromium is not resistant to hydrochloric acid, nor can it be used in the pure state because of its brittleness and difficulty to work.

e. Properties (pure).

(1) Specific gravity - 7.19.

(2) Melting point - 3,300° F.

(3) Brinell hardness No - 110 to 170.

(4) Modulus of elasticity - 36,000,000 PSI.

(5) Acid resistant (except hydrochloric).

(6) Wear, heat, and corrosion resistant.

45. COBALT (Co).

a. History. Cobalt was first recognized as an element in 1735. The chief ores of cobalt are cobaltite (CoAsS) and smaltite ($CoAs_2$). Most important deposits in the United States are found in Missouri and Pennsylvania. Cobalt is also mined in Africa, Canada, and Germany.

b. Uses. Cobalt is mainly used as an alloying element in permanent and soft magnetic materials, high-speed tool bits and cutters, high-temperature creep-resisting alloys, and cemented carbide tool bits and cutters. It is also used in making insoluble paint pigments and blue ceramic glazes.

c. Capabilities. Cobalt can be welded, machined (limited), and cold-drawn.

d. Limitations. Cobalt must be machined with cemented carbide cutters. Welding Hi-C cobalt steel often causes cracking.

e. Properties.

(1) Pure.

(a) Tensile strength - 34,000 PSI.

(b) Brinell hardness No - 125.

(c) Specific gravity - 8.9.

(d) Modulus of elasticity - 30,000,000 PSI.

(e) Melting point - 2,720° F.

(2) Alloy (Stellite 21).

(a) Tensile strength - 101,000 PSI.

(b) Modulus of elasticity - 36,000,000 PSI.

(c) Heat and corrosion resistant.

46. COPPER (Cu).

a. History. Copper was one of the first known metals and it was used extensively because of its attractive color and ability to be worked. Early Egyptians and Romans made vases and ornaments from this metal. Most copper produced today comes from sulfurized ores, "Charlocite" ($Cu_2S.Fe_2S_3$) being the most important. Arizona, Utah, and Montana are the largest producing regions. A small quantity of native copper is mined in upper Michigan. Chile and Africa are large foreign producers. Copper is a reddish metal, very ductile and malleable, and has high electrical and heat conductivity. It is used as a major element in hundreds of alloys. Commercially pure copper is not suitable for welding and, while it is very soft, it is very difficult to machine due to its high ductility.

b. Uses. The principal use of commercially pure copper is in the electrical industry where it is made into wire or other such conductors. It is also utilized in the manufacture of nonferrous alloys such as brass, bronze, and monel metal. Typical copper products are sheet roofing, cartridge cases, bushings, wire, bearings, and statues.

c. Capabilities. Copper can be forged, cast, and cold worked. It can also be welded, but its machinability is only fair.

d. Limitation. Electrolytic tough pitch copper cannot be welded satisfactorily.

e. Properties.

(1) Pure.

(a) Nonmagnetic.

(b) Brinell hardness No - 60 to 110.

(c) Tensile strength - 32,000 to 60,000 PSI.

(d) Modulus of elasticity - 16,000,000 PSI.

(e) Specific gravity - 8.9.

(f) Melting point - 1,980° F.

(g) Corrosion resistant.

(2) Alloy.

(a) Tensile strength - 50,000 to 90,000 PSI.

(b) Modulus of elasticity - 15,000,000 PSI.

(c) Brinell hardness No - 100 to 185.

f. Appearance. Copper is red in color when polished; it oxidizes to various shades of green.

g. Fracture. Copper presents a smooth surface when fractured, free from crystalline appearance.

h. Grinding wheel test. Copper gives off no sparks in this test.

i. Torch test. Because of copper's good heat-conducting properties, a larger flame is required to produce fusion of copper than would be needed for a steel piece of the same size. Copper melts suddenly and solidifies instantly. Copper alloy, containing small amounts of other metals, melts more easily and solidifies more slowly than pure copper.

j. Brasses and bronzes. Brass, an alloy of copper and zinc (60 to 68 percent copper and 32 to 40 percent zinc), has a low melting point and high heat conductivity. There are several types of brass such a naval, red, admiralty, yellow, and commercial. All vary in copper and zinc content; all may be alloyed with other elements as lead, tin, manganese, or iron; and all have good machinability and can be welded. Bronze is an alloy of copper and tin and may contain lead, zinc, nickel, manganese, or phosphorus. It has high strength, is corrosion resistant, has good machinability, and can be welded.

(1) Appearance. The color of polished brass and bronze varies with the composition from red, almost like copper, to yellow brass. They oxidize to various shades of green and brown or yellow.

(2) Fracture. The surface of fractured brass or bronze ranges from smooth to crystalline, depending upon composition and method of preparation; i.e., cast, rolled, or forged.

(3) Grinding wheel test. Brass and bronze give off no sparks.

(4) Torch test. True brasses contain zinc, which gives off white fumes when the brass is melted. Bronzes contain tin. Even a slight amount of tin makes the alloy flow very freely, like water. Due to the small amount of zinc or tin that is usually present, bronzes may fume slightly but never so much as brass.

k. Aluminum bronzes.

(1) Appearance. When polished, aluminum bronzes appear a darker yellow than brass.

(2) Fracture. Aluminum bronzes present a smooth surface when fractured.

(3) Grinding wheel test. Aluminum bronzes give off no sparks.

(4) Torch test. Welding aluminum bronzes is extremely difficult. The surface is quickly covered with a heavy scum that tends to mix with the metal and is difficult to remove.

47. LEAD (Pb).

a. History. The history of lead, one of the oldest metals known to man, dates back to the Old Testament (3,000 B.C.). The Pharaohs and Babylonians had many uses for this metal. Commercial lead is derived almost exclusively from one mineral. This material is galena, PbS, the sulfide of lead. Lead ore is mined in many countries, often in association with zinc ore. The United States (principally Missouri, Utah, Colorado, and Idaho) is the most important source followed by Australia, Canada, and Mexico.

b. Uses. Lead is used principally in the manufacture of electrical equipment such as lead-sheathed power and telephone cables and storage batteries. It is also used in building construction, in both pipe and sheet form, and in solder. Zinc alloys are utilized in the manufacture of lead weights, bearings, gaskets, seals, bullets, and shot. Many types of chemical compounds are produced from lead; among these are lead carbonate (paint pigment) and tetraethyl lead (antiknock gasoline). Lead is also used for X-ray protection. It can be said that lead has more fields of application than any other metal.

c. Capabilities. Lead can be cast, cold worked, welded, and machined.

d. Limitations. Lead has low strength with heavy weight, and lead dust and fumes are poisonous.

e. Properties.

(1) Pure.

(a) Tensile strength - 2,500 to 3,000 PSI.

(b) Modulus of elasticity - 2,600,000 PSI.

(c) Specific gravity - 11.3.

(d) Melting point - 620° F.

(2) Alloy B32-467. Tensile strength - 5,800 PSI.

(3) General.

(a) Low electrical conductivity.

(b) Self-lubricating.

(c) Malleable.

(d) Corrosion resistant.

48. MAGNESIUM (Mg).

a. History. Magnesium, ranking third in abundance, was discovered in 1830, yet its commercial history covers only 60 years. Its principal ores are dolomite, magnesite, and carnallite, but it occurs as magnesium chloride in certain natural salt brines and sea water (1 cubic mile of which contains 9 billion pounds of magnesium).

b. Uses. Magnesium is used as a deoxidizer for brass, bronze, nickel, and silver. Because of its light weight, it is used in many weight-saving applications, particularly in the aircraft industry. It is also used as a pyrotechnic for railroad signals and for military purposes. Magnesium castings are used for engine housings, blowers, hose pieces, landing wheels, and certain parts of the fuselage. Magnesium alloy materials are used in sewing machines, typewriters, and textile machines.

c. Capabilities. Magnesium can be forged, cast, welded, and machined.

d. Limitations. Magnesium in fine chip form will ignite at low temperatures (800 to 1,200° F). The flame can be smothered with suitable materials such as CO_2, foam, sand, etc.

e. Properties.

(1) Pure.

(a) Tensile strength - 12,000 PSI (cast).

(b) Tensile strength - 37,000 PSI (rolled).

(c) Brinell hardness No - 30 (cast).

(d) Brinell hardness No - 50 (rolled).

(e) Specific gravity - 1.7.

(f) Modulus of elasticity - 6,500,000 PSI.

(g) Melting point - 1,202° F.

(2) Alloy (A_z31x).

(a) Brinell hardness No - 72 (hard).

(b) Brinell hardness No - 50 (forged).

(c) Tensile strength - 42,000 PSI (hard).

(d) Tensile strength - 32,000 PSI (forged).

f. Appearance. Magnesium resembles aluminum in appearance. Like aluminum, it is highly corrosion resistant and has a good strength to weight ratio; but it is lighter in weight than aluminum. It has very low kindling point, however, and is not very weldable except when it is alloyed with manganese and aluminum. Magnesium is distinguished from aluminum by the use of a silver nitrate solution. The solution does not affect aluminum, but it leaves a black deposit of silver on magnesium. Magnesium is produced in large quantities from sea water. It has excellent machinability, but because of its low kindling point, special precautions must be used when machining.

OS 424, 1-P29

49. MANGANESE (Mn).

a. History. Manganese was first extracted as an element about 1800. The chief ore of manganese is black manganese dioxide (MnO_2).

b. Uses. Manganese is mainly used as an alloying agent in the manufacture of steel to increase its tensile strength. It is also added during the steel-making process to remove sulfur as a slag. Austenitic manganese steels are used for railroad trackwork, power shovel buckets, and rock crushers. Medium-carbon manganese steels are utilized in the manufacture of car axles and gears.

c. Capabilities. Manganese can be welded, machined, and cold-worked.

d. Limitations. Austenitic manganese steels are best machined with cemented carbide, cobalt, and high-speed steel cutters.

e. Properties.

(1) Pure.

(a) Tensile strength - 72,000 PSI (quenched).

(b) Brinell hardness No - 330.

(c) Specific gravity - 7.43.

(d) Modulus of elasticity - 23,000,000 PSI.

(e) Melting point - 2,270° F.

(f) Brittle.

(2) Alloy. Tensile strength - 110,000 PSI.

(3) General.

(a) Highly polishable.

(b) Brittle.

50. MOLYBDENUM (Mo).

a. History. Molybdenum was first prepared in 1790 in the form of metallic powder. Chief ores are molybdenite (MoS_2) and wulfenite ($PbMoO4$). Chief mines are located in Colorado, and many small deposits are found in the southwest region. Molybdenum is also found in England and New South Wales.

b. Uses. Molybdenum is used mainly as an alloying addition. Heating elements, switches, contacts, thermocouples, welding electrodes, and cathode-ray tubes are made of molybdenum.

c. Capabilities. Molybdenum can be swaged, rolled, and drawn or machined.

d. Limitations. Molybdenum can only be welded in an atomic hydrogen arc or butt welded by resistance heating in vacuum. It is attacked by nitric acid, hot sulfuric acid, and hot hydrochloric acid.

e. Properties (pure).

(1) Tensile strength - 100,000 PSI (sheet).

(2) Tensile strength - 30,000 PSI (wire).

(3) Brinell hardness No - 160 to 185.

(4) Specific gravity - 10.2.

(5) Modulus of elasticity - 50,000,000 PSI

(6) Melting point - 4,800° F.

(7) Retains hardness and strength at high temperature.

(8) Corrosion resistant.

51. NICKEL (Ni).

a. History. Nickel was first used by ancient man in swords and implements fashioned from nickel-bearing meteorites. It was first extracted as an element in 1751 from a copper-colored mineral named "kupfer nickel." Sulfide ores of nickel are found chiefly in Canada and Norway; oxidized ores occur in New Caledonia; and arsenical ores are found in Ontario, Colorado, New Mexico, France, and India. Nickel is a grayish-white metal, very ductile, and malleable.

b. Uses. Most of the nickel produced is used in the production of alloys, both ferrous and nonferrous. Chemical and food processing equipment, electrical resistance heating elements, ornamental trim, and parts subjected to elevated temperatures are all produced from nickel-containing metals. Alloyed with chromium, it is used to manufacture stainless steel.

c. Capabilities. Nickel alloys are readily welded by either the gas or arc methods. It can be machined, forged, cast, and easily formed.

d. Limitations. Nickel cannot withstand heat above 600° F in a sulfidizing atmosphere. It oxidizes very slowly in the presence of moisture or corrosive gases.

e. Properties.

(1) Pure.

(a) Tensile strength - 46,000 PSI.

(b) Brinell hardness No - 220.

(c) Specific gravity - 8.9.

(d) Modulus of elasticity - 32,000,000 PSI.

(e) Melting point - 2, 650° F.

(2) Alloy. Brinell hardness No - 140 to 230.

(3) Monel-forged.

(a) Tensile strength - 100,000 PSI.

(b) Modulus of elasticity - 26,000 PSI.

(c) High strength and toughness at elevated temperature.

f. Monel metal. Monel metal is an alloy of silver-white color containing approximately 67 percent nickel, 29 to 80 percent copper, 1.4 percent iron, 1 percent manganese, 0.1 percent silicon, and 0.15 percent carbon. In appearance, it resembles untarnished nickel. After use, however, and particularly after contact with chemical solutions, the silver-white color takes on a yellow tinge and some of the luster is lost. It has a very high resistance to corrosion and is weldable.

52. TIN (Sn).

a. History. Although it has always been a scarce metal, tin was used in ancient times even before the Christian era. Today, the work production of this metal is small, but tin is of great importance because of its many industrial uses. Tin is derived from the oxide cassiterite, SnO_2, a mineral found in nearly all parts of the world. Malaya, Boliva, China, the Belgian Congo, and Nigeria account for 90 percent of the world's tin output. No commercial tin deposits have been found, thus far, in the United States.

b. Uses. The major application of tin is in the coating of steel. It serves as the most efficient container for the preservation of perishable food. Tin, in the form of foil, is often used in wrapping food products. A second major application of tin is as an alloying element. Tin is alloyed with copper to produce various tin brasses and bronzes, with lead to produce solder, and with antimony and lead to form babbit.

c. Capabilities. Tin can be die cast, cold worked (extruded), machined, and soldered.

d. Limitations. Tin is not weldable.

e. Properties.

(1) Pure.

(a) Tensile strength - 2,800 PSI.

(b) Specific gravity - 7.29.

(c) Melting point - 450° F.

(d) Modulus of elasticity - 6,000,000 PSI.

(e) Corrosion resistant.

(2) Babbit alloy.

(a) Tensile strength - 10,000 PSI.

(b) Brinell hardness No - 30.

53. TITANIUM (Ti).

a. History. Titanium was first discovered in 1791 as the white metallic oxide rutile, TiO_2, but a relatively pure form was not isolated until 1835. It is found primarily in Florida, Virginia, and North Carolina. Today, titanium metal, the fourth most abundant structural metal in the earth's crust, is known to be widely distributed throughout the world with the largest ore deposits being mined in Quebec.

b. Uses. Titanium is used as an additive in alloying aluminum, copper, magnesium, steel, nickel, and other metals. It is also used in making powder for pyrotechnics and in the manufacture of turbine blades, aircraft firewalls, engine nacelles, frame assemblies, ammunition tracks, and mortar base plates.

c. Capabilities. Titanium can be machined at low and fast feeds, formed, spot- and seam-welded, and fusion-welded with inert gas.

d. Limitations. Titanium has low impact strength, seizing tendencies, and low creep strength at elevated temperatures (above 800° F). It can be cast into simple shapes only.

e. Properties.

(1) Pure.

- (a) Tensile strength - 100,000 PSI.
- (b) Brinell hardness No - 200.
- (c) Specific gravity - 4.5.
- (d) Modulus of elasticity - 168,000,000 PSI.
- (e) Melting point - 3,300° F.
- (f) Good corrosion resistance.

(2) Alloy.

- (a) Brinell hardness No - 340.
- (b) Tensile strength - 150,000 PSI.
- (c) High strength/weight ratio.
- (d) Twice that of Al alloy at 400° F.

54. TUNGSTEN (W).

a. History. Tungsten was discovered by the d'Elhujar brothers in 1783. (Tungsten occurs in natural state as wolframite ($FeWO_4$) and scheslite ($CaWO_4$) and is extracted in its pure state from these ores by the reduction process.) It is hard, brittle, and nonmagnetic and forms an oxide when heated in air. It is found in Colorado, California, and South Dakota, and also in Burma, China, Japan, Portugal, and Bolivia.

b. Uses. Tungsten is used in the manufacture of incandescent lamp filaments and phonograph needles and as an alloying agent in production of high-speed steel, armorplate, and projectiles.

c. Capabilities. Tungsten can be cold and hot drawn.

d. Limitations. Tungsten is hard to machine, requires high temperatures for melting, and is usually produced by powdered metallurgy (sintering process).

e. Properties.

(1) Melting point - 6,170° F plus or minus 35°.

(2) Ductile.

(3) Tensile strength - 105,000 PSI.

(4) Specific gravity - 19.32.

(5) Modulus of elasticity - 50,000,000 PSI.

(6) Thermal conductivity - 0.397.

(7) Brinell hardness No - 38.

(8) Dull white color.

55. ZINC (Zn).

a. History. Though zinc is generally regarded as a modern metal, it was probably first extracted by the Chinese in about the 13th century. Through the efforts of Marco Polo, the process was brought to Europe. The principal ores of zinc are the sulfide blends, the silicates such as willemite, and the oxides such as franklinite and zincite. Sulfide deposits of commercial importance occur in many parts of the world; namely, the United States, Belgium, and Poland. States leading in the production of zinc are Missouri, Oklahoma, and New Jersey.

b. Uses.

(1) Galvanizing constitutes the largest use of zinc and is done by dipping the part in molten zinc or by electroplating it. Examples of items manufactured in this way are galvanized pipe, tubing, sheet metal, wire, nails, bolts, etc. Zinc is also used as an alloying element in producing alloys such as brass, bronze, etc, and those alloys that are composed primarily of zinc itself.

(2) Typical parts made with zinc alloy are die castings, toys, ornaments, building equipment, carburetor and fuel pump bodies, instrument panels, wet and dry batteries, fuse plugs, pipe organs, munitions, cooking utensils, and fluxes. Other forms of zinc include zinc oxide and zinc sulfide, widely used in paints and rubber, and zinc dust which is used in the manufacture of explosives and chemical agents.

(3) An important byproduct of the zinc industry is sulfuric acid.

c. Capabilities. Zinc can be cast, cold worked (extruded), machined, and welded.

d. Limitations. The use of zinc die castings in continuous contact with steam is not recommended.

e. Properties.

(1) Pure.

(a) Tensile strength - 12,000 PSI (cast).

(b) Tensile strength - 27,000 PSI (rolled).

(c) Specific gravity - 7.1.

(d) Melting point - 790° F.

(e) Corrosion resistant.

(f) Brittle at 220° F.

(2) Alloy ASTM XXIII.

(a) Tensile strength - 41,000 PSI.

(b) Brinell hardness No - 82.

f. Zinc die castings.

(1) Appearance. Die castings are usually alloys of zinc, aluminum, magnesium, lead, and tin. They are light in weight, generally white in color (like aluminum), and frequently of intricate design. A die-cast surface is much smoother than that of a casting made in sand and is almost as smooth as a machined surface. Occasionally, die castings darkened by use may be confused with malleable iron when judged simply by appearance, but the die casting is lighter in weight and softer.

(2) Fracture. The surface of zinc die castings is white and somewhat granular in structure.

(3) Grinding wheel test. Zinc die castings give off no sparks.

(4) Torch test. Zinc die castings can be recognized by their low melting temperature. The metal boils when heated with the oxyacetylene flame. A die casting, after thorough cleaning, can be welded with a carburizing flame - tin or aluminum solders being used as filler metal. If necessary, the die-cast part can be used as a pattern to make a new brass casting.

SECTION VIII. HEAT TREATMENT

56. INTRODUCTION.

a. The main purpose in heat treating metals is to charge and improve physical properties of a metal so that it can be adapted to a specific purpose. The properties of all steels may be changed very decidedly by heating and cooling under definite conditions. The heat treating of metals consists of heating and cooling the material, while in its solid state, at a predetermined rate. An example of heat treating is when steel has been made hard to resist wear, penetration, and abrasion. This same steel can then be softened to allow for cold working or machining. Other effects of proper heat treating would include refining grain structure, removing internal stresses, and giving metals such properties as strength and toughness.

b. There are very few alloys which form perfect molten solutions and then crystallize into two or more pure metals upon solidification. Most metals will crystallize and separate in such a way that each will contain some of the other metal as a solid solution. It has been found that solids, during heating and cooling, undergo structural changes which will have considerable effect upon their physical properties.

57. CRITICAL TEMPERATURES.

a. When plain carbon steels are heated to approximately 1,340° F, the grain structure of the steel begins to change. This point is called the lower critical temperature.

b. Low-carbon steel must be heated to approximately 1,650° F before a complete grain structure is obtained. This point is called the upper critical temperature.

c. As the carbon content of the steel increases, the upper critical temperature decreases until the carbon content reaches 0.85 percent; at which point, the lower and upper critical temperatures are the same. Between 0.85 and 1.7 percent carbon content, the upper critical temperature rises abruptly.

58. QUENCHING MEDIA.

a. When a heated metal is cooled quickly, the structure is preserved. The rate of heating and cooling determines the crystalline structure of the steel since most metals have a critical temperature at which the grain structure [illegible]anges. There are two types of quenching baths:

(1) Still bath—in which the entire object is quenched.

(2) Flush bath—where the quench is forced on a desired area.

b. Common quenching media employed are as follows:

(1) Brine (usually a mixture of 10-percent salt and water), which removes heat very rapidly, is generally used in quenching plain carbon steels.

(2) Water, which removes heat rapidly sometimes causing cracking, is used only to quench heavy sections of carbon steels.

(3) Oil, which removes heat slowly thereby reducing cracking, is used to quench low-alloy steels and thin sections of carbon steel.

(4) Air, which removes heat very slowly thereby practically eliminating cracking or warping, is used primarily for high-alloy steels.

59. HARDENING STEELS.

a. Heat treatment considerably transforms the grain structure of steel, and it is while passing through the critical temperature range that steel acquires a hardening power due in part to the physical changes in the atomic structure of iron. Plain carbon steels begin to harden when heated to the lower critical temperature (approximately 1,340° F) and quenched; but they obtain their maximum hardness when heated to their upper critical temperature and quenched.

b. If the cooling is very rapid, as in water-quenching, the transformation takes place at a temperature very much below the critical temperature range. The carbon is held in a forced and finely divided state so that the steel becomes hard and brittle and a great deal stronger than slowly cooled steel. This increases the degree of hardening possible for a given cooling rate.

c. Alloy additions alter the rate of transformation on cooling and permit deeper hardening with less severe rates of cooling. This is particularly advantageous in large or complicated sections that would tend to crack or be distorted if made from plain steel and water-quenched. Each alloy or combination of alloys, however, shows individuality in its effect. Alloy steels are, therefore, made up and heat-treated to attain the specific properties required in the structures for which they are to be used. Each time a piece of carbon or low-alloy steel is heated to, or slightly above, its critical temperature, a fine grain is developed.

d. As the steel is heated to higher temperatures, the grains become coarser and continue to increase in size with the increase in the time the steel is held at these higher temperatures. Coarse-grained steels tend to be more brittle and generally less serviceable than fine-grained steels. Therefore, a fine grain is usually desired in alloy structural steels, and this is attained by quenching from a temperature not more than 100° F above the upper critical temperature.

e. Heat colors in moderate, diffused light and their approximate temperatures are as follows:

(1) Brilliant white - 2,732° F.

(2) White heat - 2,552° F.

(3) Yellow-white - 2,372° F.

(4) Orange-yellow - 2,192° F.

(5) Orange-red - 2,012° F.

(6) Bright cherry-red - 1,832° F.

(7) Cherry-red - 1,652° F.

(8) Dull cherry-red - 1,472° F.

(9) Dark red - 1,292° F.

(10) Red in sunlight - 1,077° F.

(11) Red in daylight - 975° F.

43

(12) Faint red in twilight - 885° F.

(13) Faint red in dark - 752° F.

60. TEMPERING.

a. After a steel is hardened, it is too brittle for ordinary purposes; therefore some of the hardness should be removed and toughness induced. This process of reheating quench-hardened steel to a temperature below the transformation range and then cooling at any rate desired is called tempering. The metal must be heated uniformly to a predetermined temperature depending on the toughness desired. As the tempering temperature increases, toughness increases and hardness decreases. The tempering range is usually between 370° and 750° F, but sometimes it is as high as 1,100° F.

b. Temper colors and their approximate temperatures are as follows:

(1) Very pale yellow - 430° F.

(2) Light yellow - 440° F.

(3) Pale straw-yellow - 450° F.

(4) Straw-yellow - 460° F.

(5) Deep straw-yellow - 470° F.

(6) Dark yellow - 480° F.

(7) Yellow-brown - 490° F.

(8) Brown-yellow - 500° F.

(9) Spotted red-brown - 510° F.

(10) Brown-purple - 520° F.

(11) Light purple - 530° F.

(12) Full purple - 540° F.

(13) Dark purple - 550° F.

(14) Full blue - 560° F.

(15) Dark blue - 570° F.

(16) Light blue - 640° F.

(17) Faint red (visible in dark) - 752° F.

(18) Faint red in twilight - 885° F.-

(19) Red in sunlight - 1,077° F.

c. Quench to cool part or to prevent heat from creeping during selective tempering.

61. NORMALIZING. The purpose of normalizing is to refine the grain structure of metals and remove stresses to a lesser extent than annealing. It breaks up the coarse grain structure set up from casting, welding, or forging. Normalizing is accomplished by heating to the normalizing range (100° to 200° F above the upper critical temperature) and cooling in still air.

62. ANNEALING. Metals that have been rolled, drawn, hammered, forged (work-hardened), or hardened by heating and quenching can be made soft and ductile by annealing. This process involves heating to a temperature 50° to 75° F above the upper critical temperature and cooling slowly in a furnace or other confined space. The annealing process removes hardness for further working; it also relieves stresses and increases ductility.

63. SURFACE HARDENING. A low-carbon steel cannot be hardened to any great extent because of its low carbon content, yet the surface can be hardened by means of case hardening. The hardening is accomplished by increasing the carbon content of the surface only.

a. Case hardening. This process produces a hard surface resistant to wear, but at the same time leaves a tough core. It is accomplished as follows:

(1) Pack carburizing. The process whereby work is placed in a metal container and surrounded by a mixture of charcoal or barium, calcium, or sodium carbonates. The container is sealed and heated from 1 to 16 hours at 1,700° to 1,800° F; approximate penetration is 0.007 inch per hour. Next, the work is removed, quenched, and tempered.

(2) Gas carburizing. The process whereby work is placed in a gastight retort and heated to 1,700° F, and natural or manufactured gas is passed through the retort until proper depth is obtained. Next, the work is heat-treated as in the pack process.

(3) Nitriding. The process whereby work is placed in an atmosphere of ammonia gas at 950° F for from 10 to 90 hours. The maximum depth of 0.030 inch will be reached at 90 hours. The work is then removed and cooled slowly. Little warpage will result because of the low temperature. The case must then be ground so that it will be corrosion resistant.

(4) Cyaniding. The process whereby work is preheated and immersed in a cyanide bath at 1,550° F. Time of immersion varies from a few minutes to 2 hours with a resulting penetration of 0.010 inch per hour. Parts should be tempered if toughness is desired. The fumes from this process are poisonous; therefore, the work should be performed in a well-ventilated work station.

(5) Forge case hardening. This process, usually used in the field, is accomplished by preheating work in a forge or with a torch to 1,650° F, then dipping the work in potassium cyanide or Kasenite and applying flame until the compound melts. Repeat until required depth is attained, and then quench.

b. Induction hardening. This process is accomplished by the use of a high-frequency current with low voltage and a water spray to quench the work. It is used on high-carbon and alloy steels.

c. Flame hardening. This process is accomplished by heating the surface to be hardened with an oxyacetylene torch and quenching it in water. Steel must be high in carbon.

SECTION VIII. CONCLUSION

64. SUMMARY. As a result of studying this lesson you have learned that metal has surpassed both wood and stone as a basic material for the manufacture of products. You also have become aware of the many characteristic properties that make metal so popular. In addition, you have been acquainted with the use of hardness testers, how to identify metals, production processes, and the procedures for heat treatment of metals. You should find that the knowledge you have gained by studying this lesson will be invaluable to you as you continue to study and practice the machinist trade.

LESSON EXERCISE QUESTIONS

Instructions for use of the answer sheet:

1. The procedure by which you will answer the exercise questions in this subcourse is probably new to you. The information is presented in a programed instruction format where you immediately know whether or not you have answered the questions correctly. If you have selected an incorrect answer, you will be directed to a portion of the study text that will provide you with additional information.

2. Arrange this subcourse booklet and your answer sheet so that they are convenient. Each exercise question has three choices lettered a, b, and c. Your answer sheet has three groups of numbers for questions 1 through 200. The numbers indicated for each question represent the a, b, or c choices. The exercise response list is in the appendix to this subcourse. It contains a listing of 3-digit numbers in numerical sequence. Each number is followed by a response that either reinforces a correct answer or gives you additional information for an incorrect answer.

3. To use this system proceed as follows:

a. Read the first exercise question and select the choice you think answers the question correctly. Go to the question 1 area of your answer sheet and circle the 3-digit number that corresponds with the choice you selected.

b. After you have identified the 3-digit number, locate it in the exercise response list. If you selected the right choice, the first word of the response will be "CORRECT. This tells you that you have answered the question correctly. Read the rest of the response which tells why your choice was correct and then go to the next question.

c. If the word "CORRECT" is NOT the first word of the response, you have selected the wrong answer. Read the rest of the response and then turn to the area in your study text that is mentioned. There you will find the information necessary for you to make another choice. Be sure to read all of the response because it will help you select the correct answer and it also provides more information. Line out the incorrect 3-digit response on your answer sheet.

d. After you have reread the reference, select another answer and circle the 3-digit response for that choice. Again check the number of this second choice with the response list to see if your choice is now correct and to obtain more information about your choice. If your second choice is still not correct, line out the 3-digit response on the answer sheet and continue until the correct answer is selected. When you have answered all of the questions in an exercise, count the number of lined out responses and see how well you did.

4. You will notice that the lesson exercise question numbers continue consecutively from lesson to lesson. This allows you to use one answer sheet for the entire subcourse.

5. After you have finished the exercise questions for all lessons, fold and seal the answer sheet so that the USAOC&S address is on the outside. Drop the answer sheet in the mail so the school will know you have completed the study portion of the subcourse and are now ready for the examination.

EXERCISE

1. What best describes ultimate strength?

   a. Unit stress measured in tons per square inch
   b. Unit strain measured in tons per square inch
   c. Unit stress measured in pounds per square inch

2. Which test is the one most often applied to metals?

   a. Strain
   b. Stress
   c. Tensile

3. Which is the strongest of the commercially pure metals?

   a. Molybdenum
   b. Tungsten
   c. Titanium

4. The drawing of a piece of wire from a larger to a smaller diameter is an example of

   a. ductility.
   b. toughness.
   c. elasticity.

5. The energy that is recovered from a clock spring is an example of

   a. strain.
   b. resilience.
   c. elasticity.

6. The breaking of a rotating shaft that has been drawn out of alinement by a pulley belt is an example of

   a. brittleness.
   b. fatigue.
   c. strain.

7. Which type of hardness tester operates by forcing a hardened steel ball into the test material by the weight of a known load?

   a. Shore scleroscope
   b. Rockwell
   c. Brinell

8. Which type of hardness tester is portable and can be transported to the work site?

   a. Shore scleroscope
   b. Monotron
   c. Rockwell

48

9. What best describes a metal with a type SAE 1020 designation?

   a. Carbon steel containing 0.20 hundredths of 1 percent carbon
   b. Carbon steel containing 0.10 hundredths of 1 percent carbon
   c. Nickel steel containing 0.20 hundredths of 1 percent carbon

10. Type SAE 5130 steel is a chromium-steel alloy containing

    a. 1 percent chromium and 0.30 percent carbon.
    b. 5 percent chromium and 0.30 percent carbon.
    c. 50 percent chromium and 0.30 percent carbon.

11. What is the most important single factor governing the properties and uses of steel?

    a. Slag content
    b. Carbon content
    c. Type of ore

12. Which material is not used in the charging of a blast furnace?

    a. Silicon
    b. Ore
    c. Coke

13. Which process was the first to give large quantities of cheap steel to the world?

    a. Open-hearth
    b. Bessemer
    c. Electric

14. What effect does the addition of sulfur have when added to basic open-hearth steel?

    a. Makes it free-machining
    b. Decreases the carbon content
    c. Makes it corrosion resistant

15. What ingredient provides wrought iron with the property of resisting corrosion and oxidation?

    a. Slag
    b. Scrap
    c. Carbon

16. Which is a major characteristic of an aluminum torch test?

    a. Shows red before melting
    b. White oxide film forms on molten surface
    c. Collapses suddenly

17. At what point are the upper and lower critical temperatures the same for steel?

    a. When the carbon content is below 0.85 percent
    b. When the carbon content reaches 0.85 percent
    c. When the carbon content reaches 1.7 percent

18. Which quenching media is used to reduce cracking and is primarily used for low-alloy steels and thin sections of carbon steel?

    a. Brine
    b. Water
    c. Oil

19. What process is used to induce toughness after steel has been hardened?

    a. Tempering
    b. Oil-quenching
    c. Normalizing

20. Which surface hardening process consists of preheating the metal, dipping it in potassium cyanide or Kasenite, and then applying flame until the compound melts?

    a. Forge case hardening
    b. Pack carburizing
    c. Gas carburizing

21. Which two properties are combined to form the characteristic of toughness in a metal?

    a. Ductility and strength
    b. Strength and malleability
    c. Hardness and elasticity

22. Which is a characteristic of the monotron hardness tester?

    a. Diameter of the impression is measured
    b. Depth of the impression is kept constant
    c. Depth of the impression is measured

23. What is the primary purpose of the blast furnace?

    a. Eliminating impurities in iron
    b. Refining special types of steel
    c. Extracting iron from ore

24. What type of steel is hardened by the case hardening process?

    a. Low-carbon
    b. High-carbon
    c. Low-carbon and alloy

25. What is considered to be one of the most versatile and widely used alloys?

    a. Magnesium
    b. Aluminum
    c. Chromium

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 424. . . . . Machine Shop Practice

Lesson 2 . . . . Shop Mathematics Review

Credit Hours . . . . One

Lesson Objective . . . . After studying this lesson you will be able to:

1. Work, use, solve, explain, and compute elementary mathematic problems used for shopwork application to include equations and formulas, ratio and proportion, area and volume, square root, and linear and metric measurements.
2. Measure angles and find solutions to right triangles to include the Pythagorean theorem.

Text . . . . Attached Memorandum

Materials Required . . . . None

Suggestions . . . . If possible, apply the mathematics review to various machine shop applications.

STUDY GUIDE AND ATTACHED MEMORANDUM

1. GENERAL. The purpose of this lesson is to provide a practical treatment of elementary mathematics and a discussion with illustrative examples of the mathematics involved in actual shop work. The mathematics most commonly used for shop work applications include equations and formulas, ratio and proportion, square root, linear measurements, area, volume, metric system, angular measurement, and solution to right triangles, to include the Pythagorean theorem.

2. SHOP MATHEMATICS REVIEW.

a. Equations.

(1) Definition - an equation is a statement of equality between two quantities.

Example

If $X = 2$ and $Y = 4$
$2X = Y$
And by substitution $4 = 4$

(2) Rules for solving.

(a) Equal quantities may be added or subtracted from both sides of an equation to find one unknown quantity.

Example No. 1	Example No. 2
$X - 2 = +8$	$X + 5 = 12$
$+2 = +2$	$-5 = -5$
$X = 10$	$X = 7$

(b) Problems may be solved by transposing terms; that is, any term may be transposed from one side of an equation to another by changing its sign.

Example No. 1	Example No. 2
$X + 2 = 7$	$X - 2 = 5$
$X = 7 - 2$	$X = 5 + 2$
$X = 5$	$X = 7$

(c) Equal quantities may be multiplied or divided on both sides of an equation by equal quantities.

Example No. 1	Example No. 2
$\frac{X}{5} = 7$	$4X = 20$
$\frac{X \times 5}{5} = 7 \times 5$	$\frac{4X}{4} = \frac{20}{4}$
$\frac{X \times 5}{5} = 35$	$X = 5$
$X = 35$	

(d) In general, whatever operation is performed on one side of an equation must be performed on the other side to maintain equality.

b. Formulas.

(1) A formula is a form of an equation expressing a general fact.

(2) Rules for solving.

(a) Substitute known values into the formula.

(b) Solve for unknown.

Example No. 1

$$RPM = \frac{CS \times 4}{\text{Diameter of cutter}}$$

CS = Cutting speed = 100

Diameter of cutter = 2"

$$\frac{100 \times 4}{2} = 200 \text{ r.p.m.}$$

Example No. 2

$$\text{Tap Drill Size} = OD - \frac{1}{N}$$

OD = 1/4 N = 28

$$\text{Tap Drill Size} = 1/4 - \frac{1}{28} = .214 \text{ inches}$$

c. Ratio and proportion.

(1) Ratio.

(a) Ratio is the relation which one quantity bears to another quantity of the same kind. Ratio is used considerably in shop work. Pulleys and gears may have to be figured in ratio to speed and diameters. The drawing or blueprint is a rare one, indeed, that is not drawn to some scale. Maps, without exception, are drawn to scale. Scale means one figure is used to represent another. Usually a small figure represents a larger figure; e. g., on a blueprint 1 inch might represent 1 foot.

(b) The two numbers used in the ratio are called the terms of the ratio. The first number of a ratio is called the antecedent; the second number is called the consequent. The consequent is the divisor. The (:) is the sign of ratio and means "is to." Thus, 3 : 5 reads 3 is to 5. It is a dividing sign. In the same ratio and similar expressions, such as in the same proportion and pro rata, all have the same meaning.

(c) The ratio of one number to another is really the quotient of the first number divided by the second.
For example, 8 : 2 = 4.

(d) The value of a ratio is not changed by either multiplying or dividing both terms by the same number.
Thus, 3 : 2 = 6: 4 = 60 : 40 etc.

(2) Proportion.

(a) Proportion is a statement of equality between two ratios. Thus, 3 : 4:: 6 : 8. the symbol (::) means as, or equals. Either this sign or the equal sign (=) may be used. The extremes are the first and last terms. The means are the second and third terms. X, Y or Z usually represent unknown quantities.

(b) Rules of proportion.

1. General. Rule 1 - In proportion, the product of the means equals the product of the extremes.

Example

3: 4::9:12
4 x 9 (product of the means) =
3 x 12 (product of the extremes).

Note. —This makes it possible to find an unknown quantity. In other words, when three terms of a proportion are known, the fourth can be found.

2. To find one unknown mean. Rule II - When both extremes and one mean are known, find the unknown mean by dividing the product of the extremes by the unknown mean.

Example

15: 5: = :?:20
Let X = the unknown mean.
You then write: 15:5:: X:20
15 x 20 = 5 x X
300 = 5X
60 = X, the unknown

3. To find one unknown extreme. Rule III - When both means and one extreme are known, find the unknown extreme by dividing the product of the means by the known extreme.

Example

X: 28::2:8

$$X = \frac{28 \times 2}{8}$$

X = 7.

Example problem	Solution
If a motor transport unit travels 240 miles in 8 hours, how far will it travel in 5 hours?	X: 240:: 5:8 $X = \frac{5 \times 240}{8} = 150$ miles

If 15 armatures for starting motors in military trucks cost \$63, what will 27 armatures cost at the same rate per armature?

The same relation holds between the cost prices as between the number of armatures. Therefore, the ratio of 15 armatures to 27 armatures equals the ratio of \$63 to the cost of 27 armatures.

Then: $15 : 27 = 63 : X$

$X = \frac{27 \times 63}{15} = 113.40$

27 armatures then would cost \$113.40.

d. Square root.

(1) Square root definitions.

Example

$5^2 = 5 \times 5 = 25$

(a) Exponent - placed above and to the right of a number is multiplied by itself (i.e., to what power it is to be raised).

(b) Power - the product of a number multiplied by itself a specified number of times.

(c) Root of a number - that number when multiplied by itself the number of times indicated by the exponent will result in a given number.

(d) Radical sign - indicates the root.

Example

$\sqrt[2]{\qquad\qquad}$ $\sqrt[3]{\qquad\qquad}$

Note. —A blank radical indicates a root of two.

(2) Procedure for solving square root.

(a) Whole numbers.

Example

Find the square root of $\sqrt{54756.}$

1. Insert decimal point in proper position for answer.

$\sqrt{54756.}$

2. Pair off numbers to the right and left of the decimal point.

$$\begin{array}{l} \qquad\qquad\quad . \\ \sqrt{\underset{\smile}{5}\ \underset{\smile}{47}\ \underset{\smile}{56}.\qquad} \end{array}$$

3. Select the largest square of a number that will divide into the first pair. Place this square under the first pair, and its root.

$$\begin{array}{l} \quad 2 \\ \sqrt{\underset{\smile}{5}\ \underset{\smile}{47}\ \underset{\smile}{56}.\qquad} \\ \quad 4 \\ \quad \overline{\vert\qquad\quad} \end{array}$$

4. Subtract and bring down the next pair of numbers.

$$\begin{array}{l} \sqrt{\underset{\smile}{5}\ \underset{\smile}{47}\ \underset{\smile}{56}.\qquad} \\ \quad 4 \\ \quad \overline{\vert 1\ 47\quad} \end{array}$$

5. Multiply the number of numbers in the answer by 20 - this will give the trial divisor.

20 x 2 = 40

Note. —20 is a constant and will always be used to multiply the figure or figures in the answer each time a trial divisor is required.

6. Divide the trial divisor into the new group. Place the result in the answer, and also add it to the trial divisor.

Example

$$\begin{array}{l} \quad 2\ \ 3\quad . \\ \sqrt{\underset{\smile}{5}\ \underset{\smile}{47}\ \underset{\smile}{56}.\qquad} \\ \quad 4 \\ \quad \overline{\vert 1\ 47\quad} \end{array} \qquad \begin{array}{lr} & 2 \\ & \times\underline{20} \\ \text{Trial divisor} & 40 \\ \text{Result} & +\underline{\ 3} \\ \text{Correct divisor} & 43 \end{array}$$

7. Multiply the corrected divisor by the same number just placed in the answer. Place the result below the new group and subtract.

Example

$$\begin{array}{l} \quad 2\ \ 3\quad . \\ \sqrt{\underset{\smile}{5}\ \underset{\smile}{47}\ \underset{\smile}{56}.\qquad} \\ \quad 4 \\ \quad \overline{\vert 1\ 47} \\ \quad\ 1\ 29 \\ \quad \overline{\vert\ \ 18\ 56\ } \end{array}$$

8. Repeat steps 4, 5, 6, and 7 until problem is solved.

Example

```
   2   3   4.                                     23
 √5  47  56.                                     x20
   4                     Trial divisor           460
  |1 47                  Result                   +4
   1 29                  Corrected divisor       464
    |18 56
     18 56
     00 00
```

(b) Fractions.

1. Numerator and denominator perfect square.

a. Extract square root of each.

b. Procedure same as in whole numbers.

Example

$$\sqrt{\frac{81}{256}} = \frac{\sqrt{81}}{\sqrt{256}} = \frac{9}{16}$$

2. Numerator and denominator not perfect squares.

a. Convert fraction to a decimal.

b. Proceed as in whole numbers.

(c) To square a fraction - multiply the numerator by itself and the denominator by itself.

Example

$(1/2)^2 = 1/4$

$(3/8)^2 = 9/64$

e. Linear area and volume.

(1) Formulas. Definitions of plane and solid figures.

(a) Plane figure - plane surface bounded by either straight or curved lines.

1. Polygon - plane figure bounded by straight lines.

a. Triangle - polygon bounded by three sides.

(1) Right triangle - triangle with one angle 90°.

(2) Equilateral triangle - triangle with equal sides and equal angles.

b. Parallelogram - four sided figure which has both pairs of opposite sides parallel.

(1) Rectangle - parallelogram that has four right angles.

(2) Square - parallelogram that has four right angles and four equal sides (an equilateral rectangle).

2. Circle - plane figure bounded by a curved line, every point of which is equally distant from the center of the figure.

a. Circumference - curved line that bounds a circle.

b. Diameter - straight line drawn through the center of a circle terminating at both ends on the circumference.

c. Radius - straight line drawn between the center of a circle and the circumference.

d. Arc - any part of the circumference.

e. Chord - a straight line other than a diameter, both ends terminating in the circumference.

(b) Solid figure - figure having three dimensions, length, width, and altitude.

1. Prism - solid figure whose bases are similar, equal and parallel polygons, the faces being parallelograms.

Note.—The prism is named from the shape of the bases; namely, triangular, rectangular, etc.

2. Cylinder - solid figure bounded by two equal parallel circular bases; its lateral surface is formed by moving a straight line connecting the bases and moving along their circumference.

Note.—Right cylinder is one whose lateral surface is perpendicular to its base.

3. Cone - solid whose base is a circle and whose lateral surface tapers uniformly to one point called the apex or vertex.

(2) Formulas for perimeter, area and volume.

(a) Perimeter - the outer boundary of a figure.

1. Rectangle - $P = 2L + 2W$ (fig. 1)

Example

$P = (2 \times 2') + (2 \times 4')$
$P = 4' + 8'$
$P = 12'$

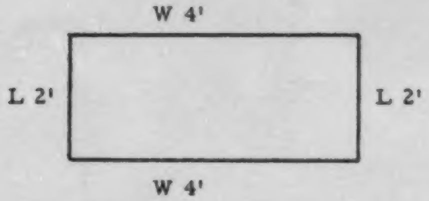


Figure 1. Rectangle (perimeter).

2. Square - $P = 4S$.

Note. —Square may be solved by using the rectangle formula since $L = W = S$.

3. Triangle - $P = a + b + c$ (fig. 2).

Example

$P = 1'' + 2'' + 3''$
$P = 6''$

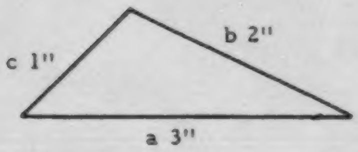


Figure 2. Triangle (perimeter).

4. Circle - $C = \pi d$ (fig. 3).

Note. —Perimeter is denoted by (C) circumference of a circle; π (Pi) = 3.1416 and is a constant. It is the ratio of the circumference to the diameter (d).

Example

$C = 5'' \times 3.1416$
$C = 15.708''$

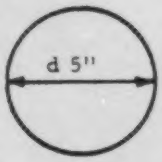


Figure 3. Circle (circumference).

(b) Area - the number of square units a surface contains.

1. Rectangle and square.

   a. Area is the product of the length and width.

   b. A = L x W.

2. Triangle.

   a. Area is the product of the length of the base and one-half the altitude.

   b. A = 1/2 b h (fig. 4).

   Example

   $A = 1/2\ (2'' \times 5'')$

   $A = \frac{10}{2}$

   $A = 5$ sq. in.

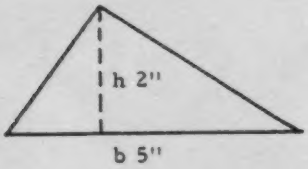


Figure 4. Triangle (area).

3. Circle.

   a. Area is the product of pi and the radius squared.

   b. $A = \pi r^2$ (fig. 5).

   Example

   $A = 3.1416 \times 2^2$

   $A = 12.5664$ sq. in.

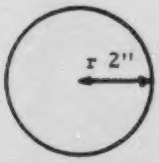


Figure 5. Circle (area).

4. Cylinder.

a. Lateral area is product of circumference and altitude: $LA = C \times h$ (fig. 6).

b. Total area is the sum of the lateral area and the areas of both bases: $TA = LA + 2 \quad r^2$ (fig. 6).

Example - Lateral area	Example - Total area
LA = (3.1416 x 6") x 10"	TA = 188.496 + 56.5488
LA = 18.8496" x 10"	TA = 245.0448 sq. in.
LA = 188.496 sq. in.	

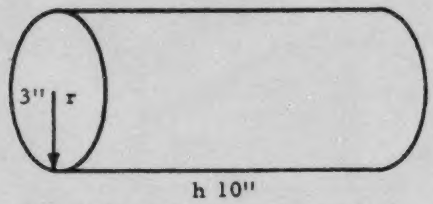


Figure 6. Cylinder (lateral and total area).

5. Cone.

a. Lateral area is the product of the circumference and one-half the slant height: $LA = C \times 1/2S$ (fig. 7).

b. Total area is the sum of the lateral area and the area of the base: $TA = LA + \pi r^2$ (fig. 7).

Example - Lateral area	Example - Total area
$LA = 18.8496 \times \frac{12}{2}$	TA = 113.0976 + 28.2744
LA = 113.0976 sq. in.	TA = 141.3720 sq. in.

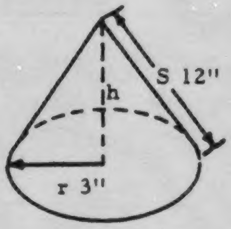


Figure 7. Cone (lateral and total area).

(c) Volume - the number of cubic units contained in a solid.

1. Rectangular prism.

a. Volume is the product of the length, width, and altitude.

b. V = l x w x h (fig. 8).

Example

V = 2' x 2' x 6'
V = 24 cu. ft.

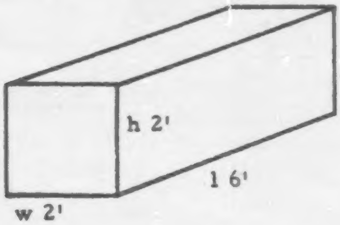


Figure 8. Rectangular prism (volume).

2. Triangular prism.

a. Volume is the product of the area of the base and one-half of the altitude.

b. V = 1/2 l w h (fig. 9).

Example

$V = \frac{6'}{2} \text{ x } 2' \text{ x } 2'$
V = 12 cu. ft.

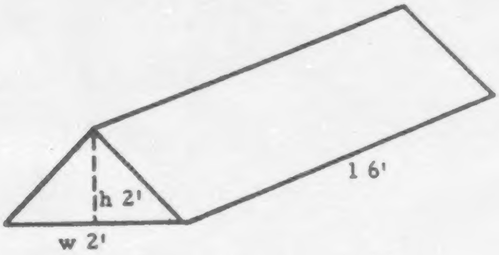


Figure 9. Triangular prism (volume).

3. Cylinder.

a. Volume is the product of the area of the base and the altitude.

b. $V = \pi r^2h$ (fig. 10).

Example

V = 3.1416 x 2^2 x 6
V = 75.3984 cu. in.

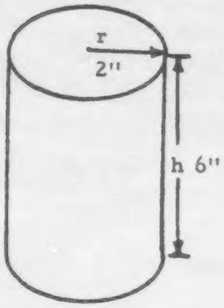


Figure 10. Cylinder (volume).

4. Cone.

a. Volume is the product of the area of the base and one-third the altitude.

b. $V = \frac{1}{3} \pi r^2 h$ (fig. 11).

Example

$V = (3.1416 \times 2^2) \times \frac{6}{3}$

$V = 25.1328$ cu. in.

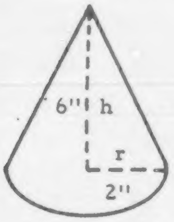


Figure 11. Cone (volume).

f. Metric system.

(1) As service section officers in the United States Army you will be often called upon to travel to some foreign countries where a different mathematical system is used. For instance the European and Asian countries use the metric system of measurement. For this reason you should have a knowledge of how the system differs from ours and how to convert their system into ours.

(2) Metric equivalence:

(a) The meter is the basic unit of measurement.

(b) One meter (m.) = 39.37 inches.

Note. —Basic units decrease or increase in multiples of ten.

(3) Fractions of meters are:

(a) 1 decimeter (dm.) = 1/10 m. or .100 m.

(b) 1 centimeter (cm.) = 1/100 or .010 m.

(c) 1 millimeter (mm) = 1/1,000 m. or .001 m.

(4) Multiples of meters are:

(a) 1 decameter = 10 meters.

(b) 1 hectometer = 100 meters.

(c) 1 kilometer = 1,000 meters.

(5) Conversion tables.

(a) To convert inches to millimeters, multiply by 25.4 because 25.4 mm = 1 inch.

Example

Change 12 inches to millimeters.
12 inches x 25.4 mm = 304.8 mm.

(b) To convert millimeters to inches, multiply by .03937. 1 mm = 0.03937 inches.

Example

Change 73 mm to inches.
73 mm x 0.03937 inch = 2.874 inches.

g. Units of angular measurement.

(1) Degree (1°).

(2) One revolution of a circle contains 360°.

(3) Half a revolution contains 180°.

(4) A right angle contains 90°.

(5) Each degree contains 60 minutes (1').

(6) Each minute contains 60 seconds (1").

Note. —Seconds are used for extremely accurate work. In machine shop work, the vernier bevel protractor measures to the nearest 5 minutes in accuracy.

(7) Addition and subtraction of angles.

Examples

$$\begin{array}{r} 15^\circ\ 46'\ 34'' \\ +\ 37^\circ\ 23'\ 42'' \\ \hline 52^\circ\ 69'\ 76'' \end{array} \qquad \begin{array}{rcr} 32^\circ\ 13'\ 32'' & = & 31^\circ\ 12'\ 92'' \\ -\ 25^\circ\ 56'\ 47'' & & 25^\circ\ 56'\ 47'' \\ \hline \text{Which is} & & 6^\circ\ 16'\ 45'' \end{array}$$

Which is $53^\circ\ 10'\ 16''$

h. Solutions of right triangles.

(1) Trigonometry is that branch of mathematics which deals with the numerical relations between the sides and angles of a triangle. The trigonometric functions discussed here will be the sine, cosine, and tangent. Practically all common shop problems in right angle trigonometry can be solved by means of these functions. The solving of tapers in lathe work is a significant example of where knowledge of right triangles is important.

Note.—The sum of the angles of any triangle equals 180°.

(2) Nomenclature of right triangles (90° triangles) (fig. 12).

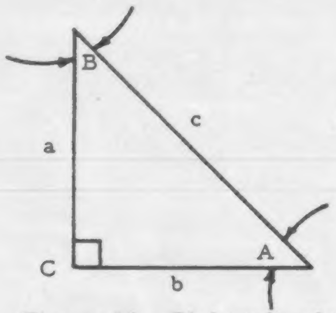


Figure 12. Right triangle.

(a) In reference to angle A.

1. Side opposite = a. Side a is opposite the angle referred to.

2. Side adjacent = b. Side b touches the angle referred to.

3. Hypotenuse = c. The hypotenuse is always opposite the 90° angle in a right triangle.

(b) In reference to angle B.

1. Side opposite = b. Side b is opposite the angle being referred to.

2. Side adjacent = a. Side a touches the angle referred to.

3. Hypotenuse = c. The hypotenuse is always opposite the 90° angle in a right triangle.

(c) Example (reference angle A) (fig. 13).

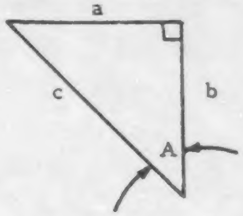


Figure 13. Right triangle.

1. Side opposite = a.

2. Side adjacent = b.

3. Hypotenuse = c.

(d) Example (reference known angle - 40°) (fig. 14).

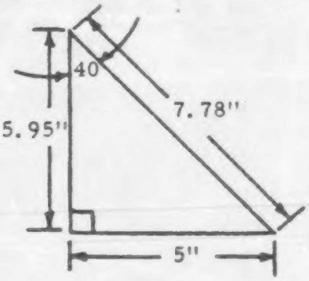


Figure 14. Right triangle.

1. Side opposite = 5.000 inches.

2. Side adjacent = 5.95 inches.

3. Hypotenuse = 7.78 inches.

(e) Example (reference unknown angle) (fig. 15).

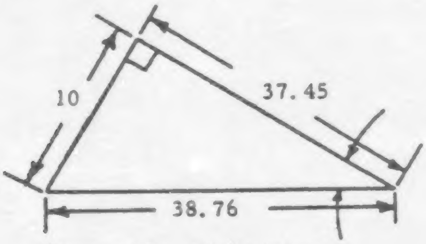


Figure 15. Right triangle.

1. Side opposite = 10.

2. Side adjacent = 37.45.

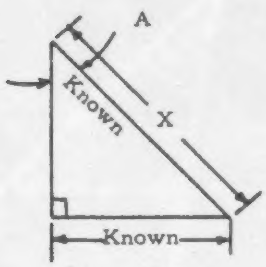
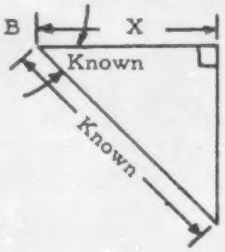
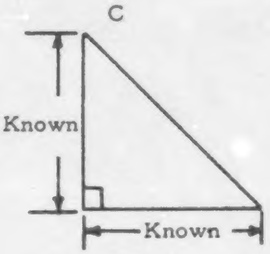
3. Hypotenuse = 38.76.

(3) Trigonometric functions.

Note. —The term function in mathematics is a quantity whose value depends on the value of some other quantity.

Example. - In a square the length of one side depends on the length of the other sides. Also the length of a diagonal line across the corners is dependent on the length of the sides.

(a) When one angle other than the right angle and a side is known, the length of the other two sides can be found. If two sides are known we can determine the size of either of the two angles by the use of trigonometric functions.

We can find hypotenuse. (fig. 16A)

We can find the adjacent side. (fig. 16B)

We can find the angles. (fig. 16C)

Figure 16. Known and unknown quantities of right triangle.

		AIDS TO MEMORY
1.	Sine $= \frac{\text{side opposite}}{\text{hypotenuse}}$	Sine $= \frac{\text{Oscar}}{\text{Has}}$
2.	Cosine $= \frac{\text{side adjacent}}{\text{hypotenuse}}$	Cosine $= \frac{\text{A}}{\text{Heap}}$
3.	Tangent $= \frac{\text{side opposite}}{\text{side adjacent}}$	Tangent $= \frac{\text{Of}}{\text{Apples}}$

(b) Selection of functions = select a function containing two known values and the one unknown you are looking for.

Note. —An extract of trigonometric tables will be found at the end of this lesson.

Example. - Find degrees in angle X (fig. 17).

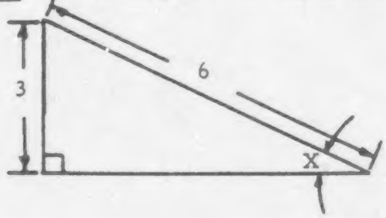


Figure 17. Right triangle (angle X unknown).

Determine what function to use. Ans. - Sine.

REASON: The side opposite (3) and the hypotenuse (6) are known. We are looking for the sine of angle X.

$$\text{Sine} = \frac{\text{Side opposite}}{\text{Hypotenuse}} = \frac{3}{6} = \frac{1}{2} = 0.500$$

Answer to problem:
Sine of 0.500 = 30°
∠LX = 30°

EXAMPLE. - Find the length of side X (fig. 18).

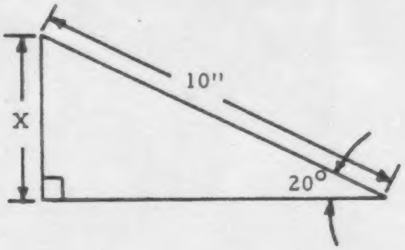


Figure 18. Right triangle (side opposite unknown).

Determine what function to use. Ans. - Sine

REASON: The angle (20°) can be used and hypotenuse (10") is known. We are looking for the opposite side.

$$\text{Sine} = \frac{\text{Side opposite}}{\text{Hypotenuse}}$$

Sine of 20° = 0.34202

$$0.34202 = \frac{X}{10}$$

X = .34202 x 10
X = 3.4202 inches

(4) Law of the right triangle.

(a) The law of the right triangle is known as the Pythagorean theorem. This theorem is used when there are two known sides and one unknown side to a right triangle. It states:

$$H^2 = A^2 + B^2 \qquad H = \sqrt{A^2 + B^2}$$

Example 1 (fig. 19) - The hypotenuse $H^2(5^2)$ = Side $A^2(3^2)$ + Side $B^2(4^2)$

$H^2 = A^2 + B^2$

$25 = 9 + 16$

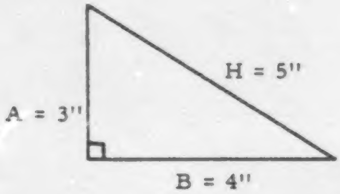


Figure 19. Pythagorean theorem.

Example 2 (fig. 20) - Solve for hypotenuse H.

$H^2 = A^2 + B^2$

$H^2 = 6^2 + 8^2$

$H^2 = 36'' + 64''$

$H^2 = 100''$

$H = \sqrt{100}$

$H = 10''$

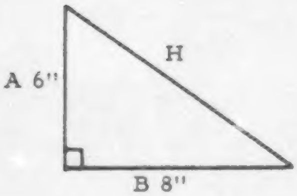


Figure 20. Solving for unknown hypotenuse.

(b) The Pythagorean theorem can also be revised to include the following formulas:

1. $A^2 = H^2 - B^2$

2. $B^2 = H^2 - A^2$

TABLE I. EXTRACT FROM SINES AND COSINES, NATURAL

′	20°		21°		22°		23°		24°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.34202	.93969	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.34229	.93959	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.34257	.93949	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.34284	.93939	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.34311	.93929	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.34339	.93919	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.34366	.93909	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.34393	.93899	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.34421	.93889	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.34448	.93879	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.34475	.93869	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.34503	.93859	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.34530	.93849	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.34557	.93839	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.34584	.93829	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.34612	.93819	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.34639	.93809	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.34666	.93799	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.34694	.93789	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.34721	.93779	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.34748	.93769	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.34775	.93759	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.34803	.93748	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.34830	.93738	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.34857	.93728	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.34884	.93718	.36515	.93095	.38134	.92544	.39741	.91764	.41337	.91056	35
26	.34912	.93708	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.34939	.93698	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.34966	.93688	.36596	.93063	.38215	.02410	.39822	.91729	.41416	.91020	32
29	.34993	.93677	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.35021	.93667	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.35048	.93657	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.35075	.93647	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.35102	.93637	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.35130	.93626	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.35157	.93616	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.35184	.93606	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.35211	.93596	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.35239	.93585	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.35266	.93575	.36894	.92945	.28510	.92287	.40115	.91601	.41707	.90887	21
40	.35293	.93565	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.35320	.93555	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.35347	.93544	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.35375	.93534	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.35402	.93524	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.35429	.93514	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.35456	.93503	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.35484	.93493	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.35511	.93483	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.35538	.93472	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.35565	.93462	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.35592	.93452	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.35619	.93441	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.35647	.93431	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.35674	.93420	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.35701	.93410	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.35728	.93400	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.35755	.93389	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.35782	.93379	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.35810	.93368	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	69°		68°		67°		66°		65°		

Note.—For angles of 0 to 45° read down with minutes on left-hand side. For angles 45 to 90° read up with minutes on right-hand side.

TABLE II. EXTRACT FROM TANGENTS AND COTANGENTS, NATURAL

′	40°		41°		42°		43°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	53
8	.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	33
28	.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	14
47	.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	3
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	2
59	.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	1
60	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	49°		48°		47°		46°		

3. SUMMARY. This lesson provided you with a practice treatment of elementary mathematics and a discussion with illustrative examples of the mathematics involved in actual shopwork. If you have mastered this shop mathematics review you will be proficient enough for shopwork applications including equations and formulas, ratio and proportion, square root, linear measurements, area, volume, metric system, angular measurement, and solutions to right triangles.

EXERCISE

26. What is the value of Y in the equation 4Y + 36 = 6Z - 12, when Z = 2/3?

a. -11
b. 11
c. 7

27. If a driving gear that has 39 teeth meshes with a driven gear having 26 teeth and turning at 510 RPM, what is the RPM of the driving gear?

a. 170
b. 340
c. 610

28. What is the square of the square root of 225?

a. 15
b. $\sqrt{15}$
c. 225

29. What is the square root of 7.29?

a. 2.7
b. 0.27
c. 2.6

30. The exterior walls of a building 60 feet long and 30 feet wide are to be painted. The volume of the building is 18,000 cubic feet. If 10 cans of paint each covering 200 square feet are purchased, how many cans will be left when the job is complete?

a. 0
b. 1
c. 3

31. What is the circumference (inches) of the largest ball bearing that can be machined from a 4-inch cube of steel stock?

a. 12.65
b. 12.56
c. 6.28

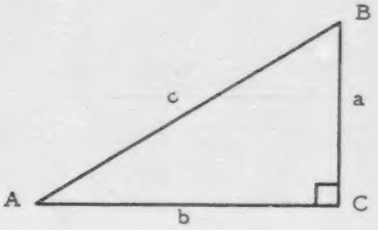
32. If the diameter of a bearing is 120 millimeters, what is the diameter in inches?

a. 0.4724
b. 0.5724
c. 4.7244

33. If angle A of a triangle equals 45° 27' 01" and angle C equals 43° 43' 04", what is the value of angle B?

    a. 90° 49' 55"
    b. 90° 10' 05"
    c. 89° 70' 05"

Note. - Problems 34 and 35 refer to the following figure.



34. If side a is 20 inches and angle A is 41° 25', what is the length of side b in inches?

    a. 22.67
    b. 19.74
    c. 2.25

35. If side a is 93 inches and side c equals 155 inches, how many inches does side b equal?

    a. 15,376
    b. 122
    c. 124

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 424	Machine Shop Practice
Lesson 3	Blueprint Reading and Sketching
Credit Hours	Three
Lesson Objective	After studying this lesson you will be able to: 1. Read blueprints used in a metalworking shop. 2. Explain how sketches are used for conveying ideas to other people and technicians.
Text	Attached Memorandum
Materials Required	None
Suggestions	Pay particular attention to the figures provided.

STUDY GUIDE AND ATTACHED MEMORANDUM

SECTION I. BLUEPRINT READING

1. INTRODUCTION.

a. A picture is worth a thousand words. Man has used pictures as a means of communication for many years. It would be almost impossible for an engineer or an inventor to describe the size and shape of a simple object without a drawing of some kind. For example, if an engineer designed a simple object such as an oil filter bracket, it would be very difficult to convey the idea to a person who was to fabricate the object without some type of drawing to show the size and shape of the object and the location of the necessary holes.

b. Drawing or sketching is the universal language used by engineers, technicians, and skilled craftsman. Whether this drawing is made freehand or by the use of drawing instruments, as in the preparation of a mechanical drawing, it is needed to convey all the necessary information to the individual who will fabricate and assemble the object. It makes no difference whether the drawings are for fabricating and assembling or building ships, aircraft, or a mechanical device, the need for clear and understandable drawings exists. If many people are involved in the fabricating of the object, copies must be made of the original drawing or tracing so that all persons involved will have the same information.

2. PRODUCING BLUEPRINTS.

a. Blueprints are reproduced copies of mechanical or other types of technical drawings. A mechanical drawing is drawn with instruments such as compasses, ruling pens, T-squares, triangles, and French curves. The prints are reproduced from the original drawings in much the same manner as photographic prints are reproduced from negatives. The original drawings for the prints are made by drawing directly on, or tracing a drawing on, a translucent tracing paper or cloth using black waterproof (India) ink or a special pencil. This original drawing is normally referred to as a tracing or master copy. The copies of the tracings are rarely, if ever, sent to a shop; rather, reproductions of these tracings are made and distributed to persons or offices where needed.

b. Blueprints are made from these tracings. The word blueprint is a rather loosely used term when dealing with reproductions of original drawings. One of the first processes devised to reproduce or duplicate tracings produced white lines on a blue background, hence the term blueprints. Today, however, other methods of reproduction have been developed, and they produce prints of different colors. These colors may vary between brown, black, gray, or maroon. The differences lie in the types of paper and the developing processes used.

c. A patented paper identified as "BW" paper produces prints with black lines on a white background. The ammonia process or "OZALIDS" produces prints with black, blue, or maroon lines on a white background. Other processes that may be used to reproduce drawings, usually small drawings or sketches, are the office type duplicating machines such as the mimeograph and ditto machines. Another type of duplicating process used for reproducing working drawings is the photostatic process. This is, in reality, a photographic process in which a large camera reduces or enlarges a tracing or drawing. The photostat has white lines on a dark background when reproduced directly from a tracing or drawing. If the photostated print is then reproduced, it will have brown lines on a white background.

3. ORTHOGRAPHIC PROJECTION.

Prints that furnish complete information for construction and repair present an object in its true proportions. These prints are accurate and indicate true shape and size. The prints are usually drawn by orthographic projection, which consists of a parallel projection in which the projectors are perpendicular to the plane of projection.

b. The number of views to be used in projecting a drawing is governed by the complexity of the shape of the drawing. Complex drawings may be drawn showing six views; namely, top, bottom, left side, front, right side, and rear. Figure 1 shows an object placed in a transparent box hinged at the edges. The projections on the sides of the box are the views seen by looking straight at the object through each side. If the outlines are scribed on each surface and the box is opened as shown in figure 2, the result is a 6-view orthographic projection drawing as shown in figure 3. It will be helpful to study these three figures and try to mentally picture the block as it is unfolded and layed out in figure 3. As a general rule, you will find that most drawings will be presented in three views, although you will occasionally see a 2-view drawing. This is especially applicable to cylindrical objects.

c. A 3-view orthographic projection drawing will generally show the front, top, and right side. Figure 4 illustrates how these views are seen by the draftsman. By referring back to figure 3 and eliminating the rear, bottom, and left side views, the drawing is changed from a 6-view drawing to the more conventional 3-view drawing. The completed 3-view drawing with dimensions is shown in figure 5. The arrangement of the three views should be studied. The front view is the starting point since it shows the most characteristic feature of the object—the notch. The right side or end view is projected to the right of the front view.

It should be noted that all of the horizontal outlines of the front view are extended horizontally to make up the side view. After you study each view of the object, you should be able to visualize the object as it appears in figure 6. In order to clarify the 3-view drawing further, think of the object as being immovable and that you are moving around it. This will help you to relate the blueprint views to the appearance of the object concerned.

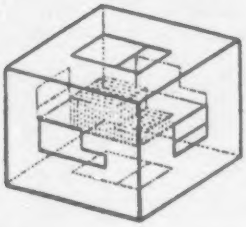


Figure 1. Visualizing six views.

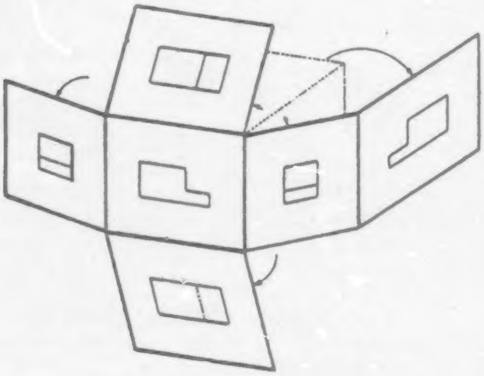


Figure 2. Opening the six views.

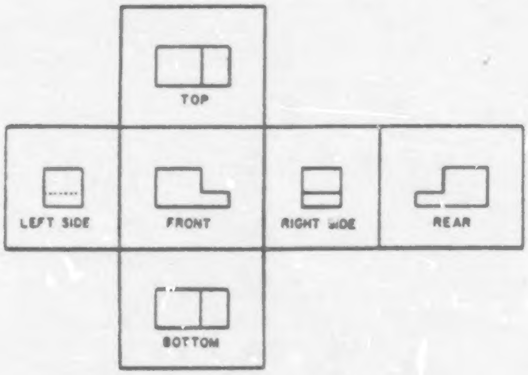


Figure 3. A six-view drawing.

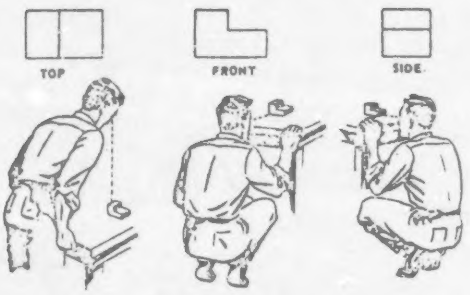

TOP
FRONT
SIDE

Figure 4. Three orthographic views of a block.

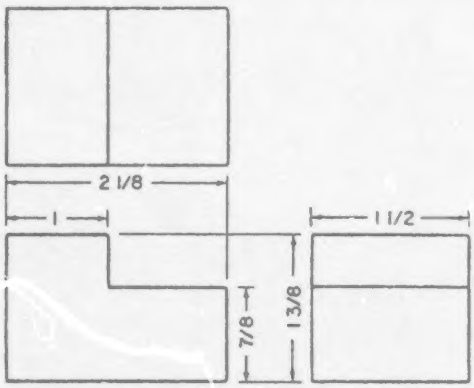

2 1/8
1
1 1/2
7/8
1 3/8

Figure 5. Completed 3-view drawing.

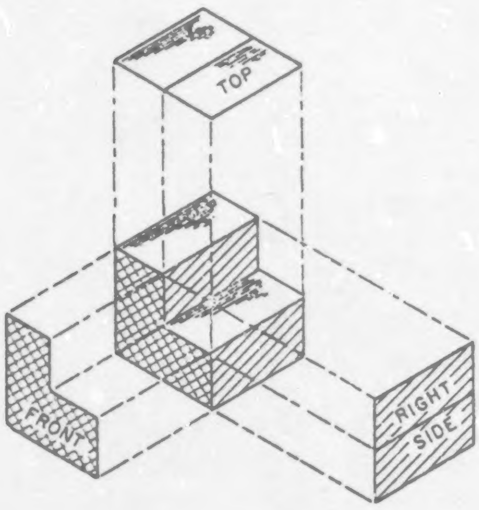

TOP
FRONT
RIGHT SIDE

Figure 6. Pull off the views.

4. PICTORIAL DRAWINGS. The purpose of a pictorial drawing is to show the general location, function, and appearance of parts and assemblies. There are three common types of pictorial views drawn by draftsmen. They are perspective, isometric, and oblique.

a. Perspective drawing. Perspective, or central projection, excels all other types of projection in the pictorial representation of objects. It is called the geometry of photography, to which it is closely related, and is the type of drawing used for ordinary illustration work. It may be a simple outline drawing, or it may be an actual photographic reproduction with infinite detail and blending of light and shade. It is a drawing of an object as it appears to the eye of the draftsman. On first thought, this would seem to be the ideal form of drawing, but such is not the case. It is defective from the standpoint of showing how an article is to be constructed. This characteristic makes it of little value as a plan for a workman to work from (fig 7 and 8).

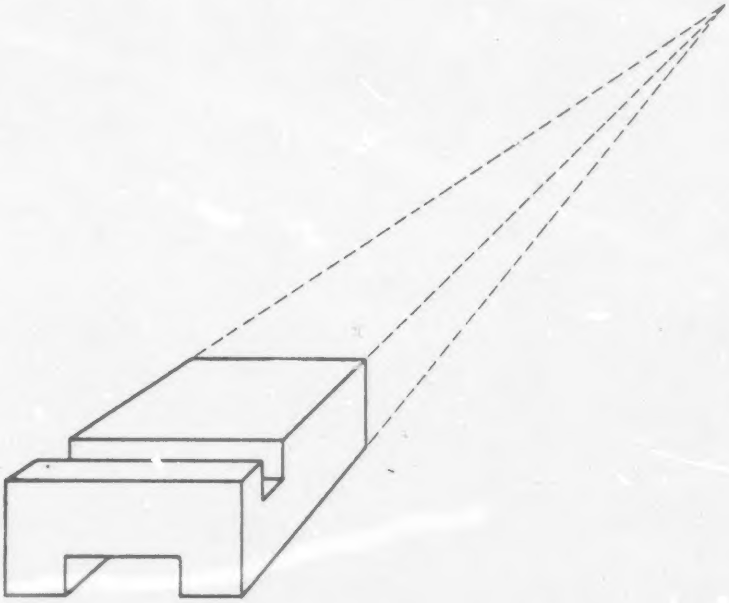


Figure 7. Perspective drawing with one vanishing point.

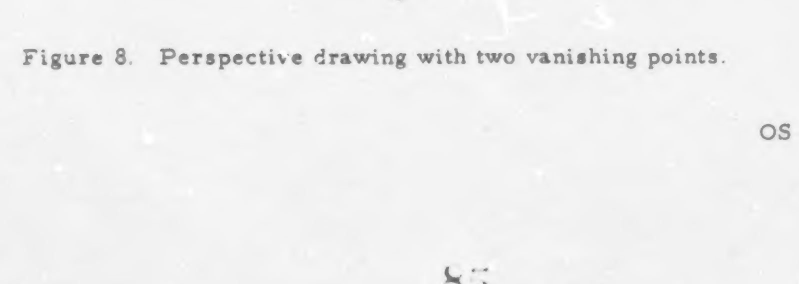


Figure 8. Perspective drawing with two vanishing points.

b. Isometric drawing. The isometric drawing is the most commonly used and the most useful in making freehand sketches. In an isometric drawing, all lines that are parallel on the object are also parallel on the drawing. Vertical lines are shown in a vertical position, but lines representing horizontal lines are drawn at an angle of 30° with the horizontal. Also, on an isometric drawing, all lines which represent the horizontal and vertical lines on an object have true length. Due to the fact that all isometric lines are spread equally (120°), the same scale of measure is used on the three visible sides. Isometric drawings (fig 9) may be dimensioned and blueprints of these drawings may be used for making simple objects. It is extremely difficult to use isometric drawings alone for complicated parts or structures. It has been found, however, that isometric drawings may be effectively used as an aid in clarifying the orthographic drawings that are the foundation of all blueprints.

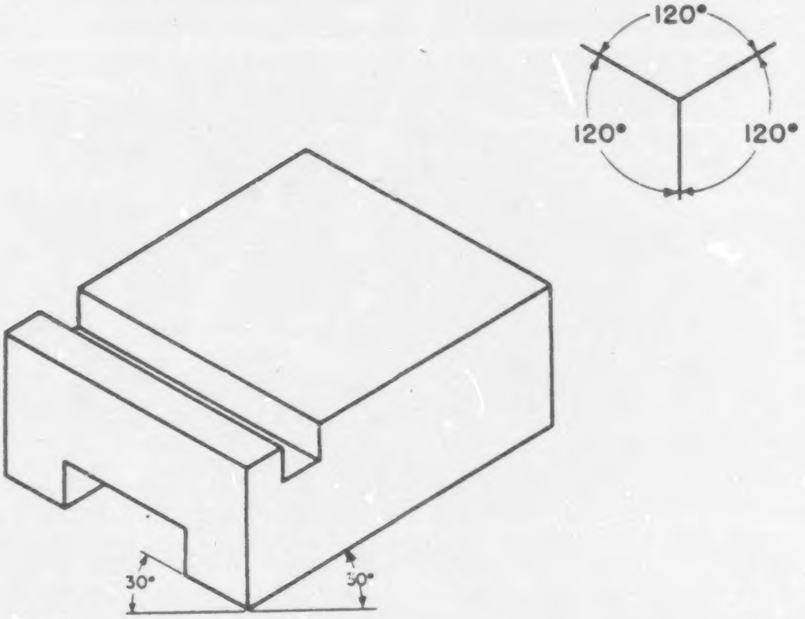
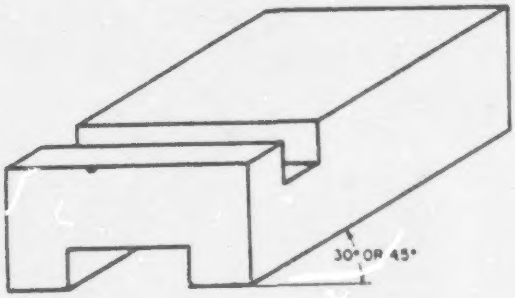


Figure 9. Isometric drawing.

c. Oblique drawing. In an oblique drawing (fig 10), the front face of the object is shown in its true size and shape as if it were an orthographic drawing. The receding lines of the other two sides shown are then drawn obliquely at any angle. This angle is usually 30°, 45°, or 60° to the horizontal. The measuring scale for the oblique sides may be any selected scale to give the object realistic depth. This is normally three-quarters of the scale of the front view.



5. SPECIAL VIEWS. In many complex objects it is often difficult for draftsmen to show true size and shapes of an object orthographically. Therefore, the draftsmen must use some other media to give the engineer and craftsman a clear picture of the object to be constructed. Included in these media are auxiliary views, details, section views, phantom views, exploded views, and developments.

a. Auxiliary views. An auxiliary view is often necessary to clearly show the true shape and length of inclined surfaces or other features which are not parallel to any of the principal planes of projection. An example of this is shown in figure 11. If the front and bottom views were the only ones shown, it would be impossible to determine the size and shape of the cutouts in each end. For a case like this, the draftsman would use the auxiliary view to show the true shape and size. These views are obtained by looking directly at the inclined surfaces.

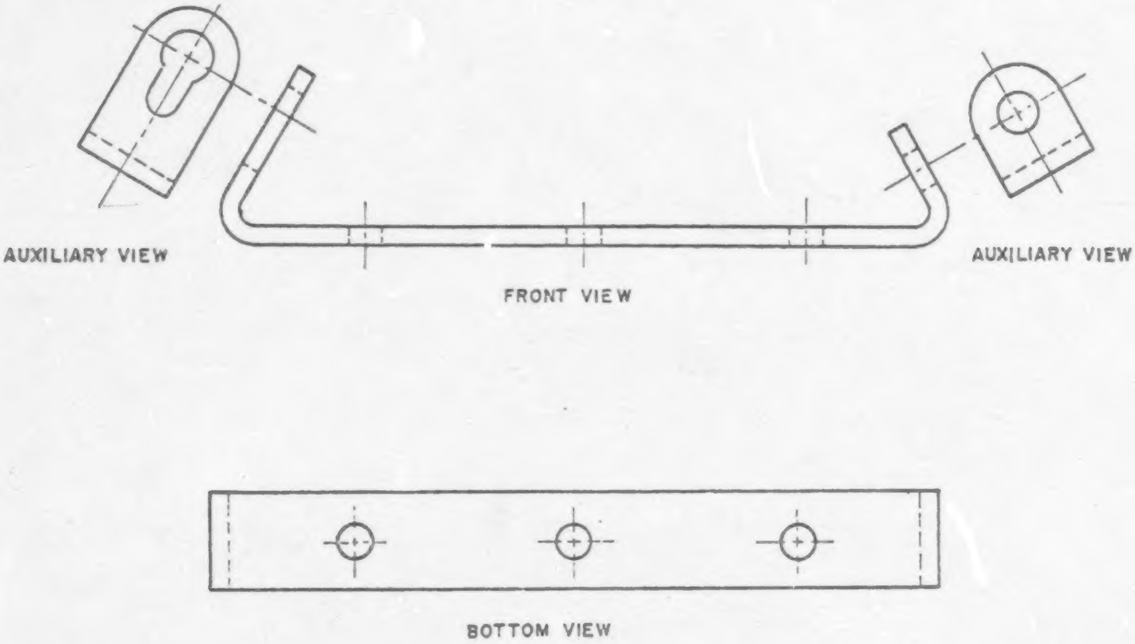


Figure 11. Right and left auxiliary views.

b. Phantom views. Phantom views are used to indicate the alternate position of parts of the item drawn, repeated details, or the relative position of an absent part. Figure 12 shows a phantom view of a part in the alternate position. This is shown as the part to the left of the figure.

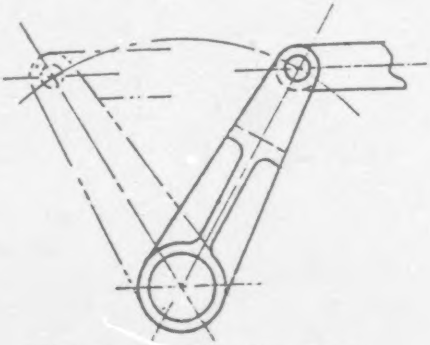


Figure 12. Phantom views.

c. Section views. Section views are used to give a clearer view of the interior or hidden feature of an object which normally cannot be clearly observed in conventional outside views. This type of view is obtained by cutting away part of an object to show the shape and construction at the cutting plane. When sectional views are drawn, the part that is cut by the cutting plane is marked with diagonal parallel section lines. To the draftsman, this is known as crosshatching. When two or more parts are shown in one view, each part is sectioned or crosshatched with a different slant line. The section views are necessary for a clear understanding of complicated parts and for some simple drawings—a section may serve the purpose of an additional view. Figure 13 shows an example of a full sectional view. Note the cutting plane line in the top view and the direction of the arrows. The direction of these arrows indicates the particular part of the object that is shown in the section view. The placement of the top view directly over and in line with the section view should also be noted. This placement provides for a better and more understandable reading of the drawing.

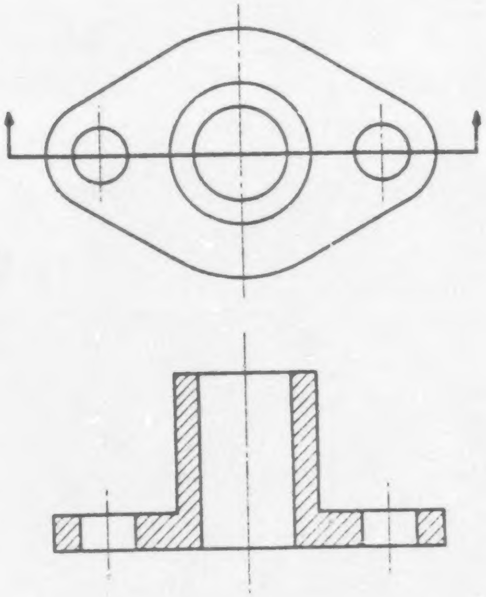


Figure 13. Full section.

(1) Offset section. A section view which has the cutting plane changing direction backward and forward (zig-zag), so as to pass through features that are important to show, is known as an offset section. The offset cutting plane in figure 14 is arranged so that the three different sizes and shapes of holes will be shown in the section.

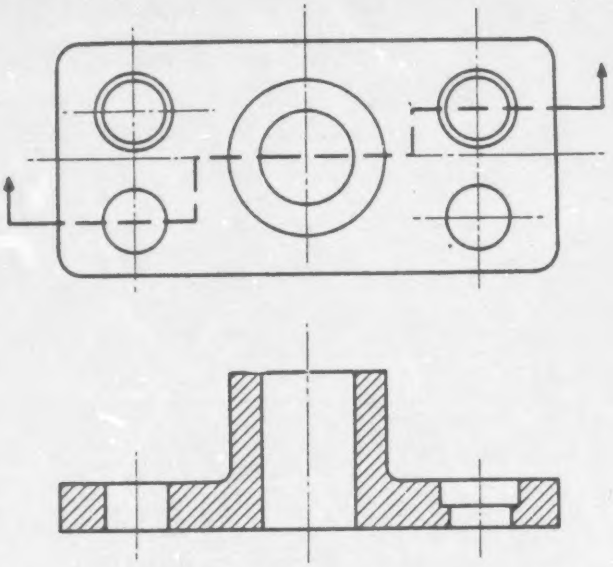


Figure 14. Offset section.

(2) Half section. A half section (fig 15) is normally used when the object is symmetrical in both outside and inside details. One half of the object is sectioned; the outer half is shown as a standard view. The object in figure 14 is round as if it were cut into two equal parts and then those parts divided equally, you would have four quarters. Now remove one of the quarters. This is what the cutting plane line has done in the top view of figure 15. This has allowed you to look inside the object and see the shape while still being able to see the configuration of the outside. It must be understood that if the cutting plane had extended along the diameter of the cylinder, you would have been looking at a full section. The cutting plane in this drawing, however, extends the distance of the radius, or only half the distance of a full section, hence it is called a half section.

(3) Revolved section. The draftsman uses a revolved section to eliminate extra views of rolled shapes, ribs, and similar forms. It is really a drawing within a drawing, and it clearly describes the objects' shape at a certain cross section station or point. The revolved sectional view (fig 16) provides you with a look at the rib head-on. Due to the revolving feature of the drawing, this kind of section is called a revolved section.

(4) Removed sections. A removed section (fig 17) is normally used to illustrate particular parts of an object. It is drawn like the revolved section with the exception of it being placed at one side of the main drawing. A removed section is often drawn to a larger scale than the view which it indicates. This is done to provide a clearer and more detailed view of the particular object.

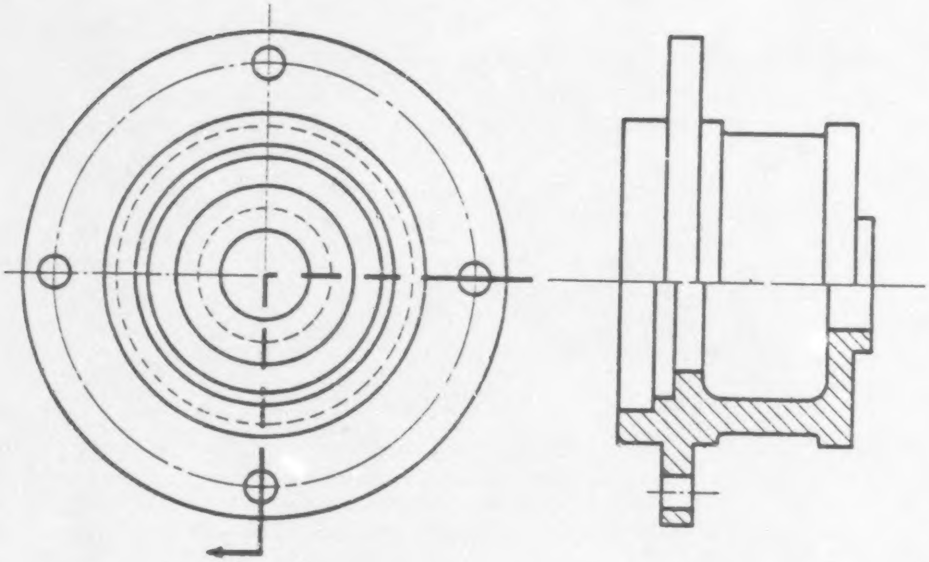


Figure 15. Half section.

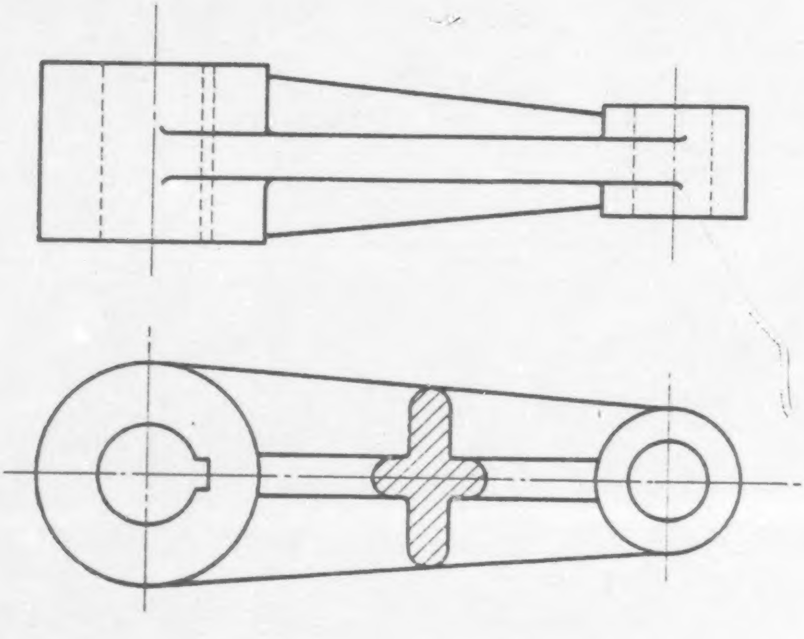


Figure 16. Revolved section.

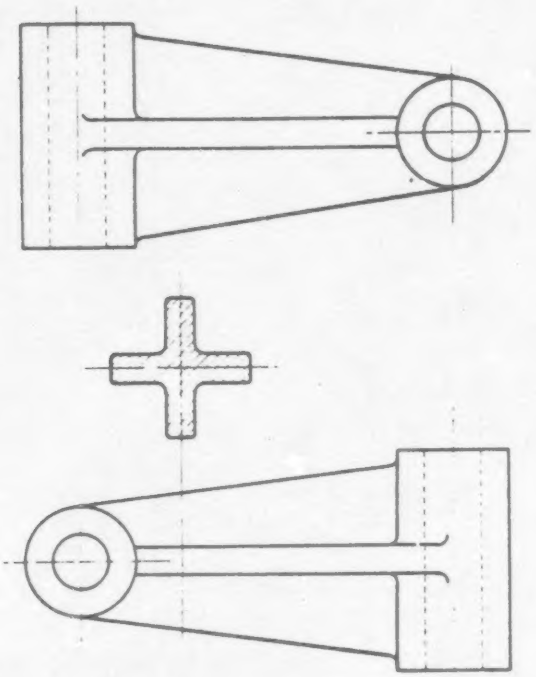


Figure 17. Removed section.

(5) Broken-out section. The inner structure of a small area may be shown by peeling back or removing the outside surface (fig 18). The details of this particular bolt would be very difficult to show with any other type of drawing.

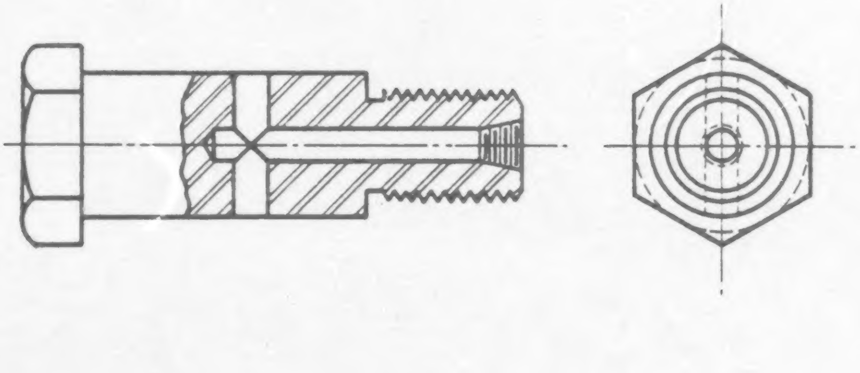


Figure 18. Broken-out section.

(6) Alined section. When a true sectional view might be misleading, parts such as ribs or spokes are drawn as if they are rotated into or out of the cutting plane. By looking at the front view of figure 19, it can be seen that the cutting plane line AA goes between two spokes in the bottom of the view, and splits a spoke at the top of the view. Section A-A, however, does not show the true drawing as indicated by the cutting plane line. If this was the case, the top spoke in section A-A would be crosshatched, indicating that it had been cut in half by cutting plane line AA. The top spoke in section A-A has been realined for the purpose of providing a clearer and more understandable section view.

6. LINE CONVENTIONS.

a. Types of lines.

(1) Ink lines. All ink lines should be opaque and of uniform width throughout. There are three widths of ink lines used: thin, medium, and thick. The ink line widths are in proportions of 1:2:4. The actual width of each type of line is governed by the size and style of the drawing.

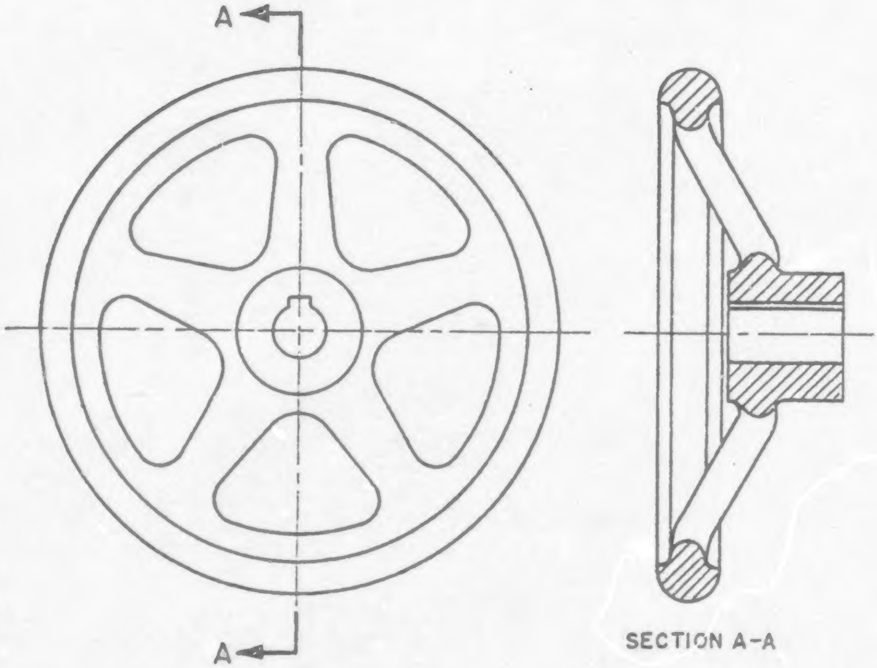


Figure 19. Alined section.

(2) Pencil lines. Pencil lines should be of uniform width and should have the same contrast or degree of blackness throughout the line. Care must be exercised to insure that the pencil lines are sufficiently dense to reproduce continuous solid lines.

b. Line characteristics. Cutting and viewing plane lines are the thickest lines on the drawing. The "outline" and other visible lines should be drawn prominently. Hidden, sectioning, center, phantom, extension, dimension, and leader lines should not be as prominent as "outlines." Opaque, black, well-spaced lines and letters should be used to insure high-quality reproduction.

(1) Parallel lines. All parallel lines should be held to a minimum of 0.03 inches between lines.

(2) Center lines. Center lines are composed of long and short dashes, alternately spaced with a long dash at each end. Center lines should touch whenever they cross so as to provide an exact center location. Whenever short center lines are necessary, they may be drawn unbroken provided there is no confusion with other lines. Center lines should also be used to indicate the travel of a center (fig 21b and 22).

(3) Dimension lines. Dimension lines should terminate with an arrowhead or dot at each end. They should be unbroken except where space is required for the dimension (fig 21b and 22). Additional information concerning dimension lines is provided in paragraph 7c.

(4) Leaders. Leader lines should be used to indicate a part or portion to which a number, note, or other reference applies, and they should be terminated with an arrowhead or dot (fig 21a and 22).

(5) Break lines. Short breaks should be indicated by solid, freehand lines. For long breaks, full ruled lines with freehand zig-zags should be used. Shafts, rods, tubes, etc, having a portion of their length broken out, should have the ends of the break drawn as indicated in figures 20 and 21a.

(6) Phantom lines. Phantom lines are used to indicate the alternate position of parts, repeated detail, or the relative position of an absent part. These lines are composed of alternating one long and two short dashes evenly spaced with a long dash at each end (fig 21a and 22).

(7) Sectioning lines. Sectioning lines are used to indicate the exposed surfaces of an object in a sectional view. The spacing of sectioning lines may vary according to the shape and size of the part, but they should never be closer than necessary for clarity (fig 21a and 22).

(8) Extension lines. These lines are used to represent the surface of an object for dimensioning purposes (fig 21b and 22). Extension lines are discussed in paragraph 7d.

(9) Hidden lines. Hidden lines consist of short dashes evenly spaced. These lines are used to show the hidden features of a part. They should always begin and end with a dash in contact with the line from which they start or end, except when such a dash would form a continuation of a full line. Dashes should touch at the corners and arcs should start with dashes at the point of tangency (fig 21b and 22).

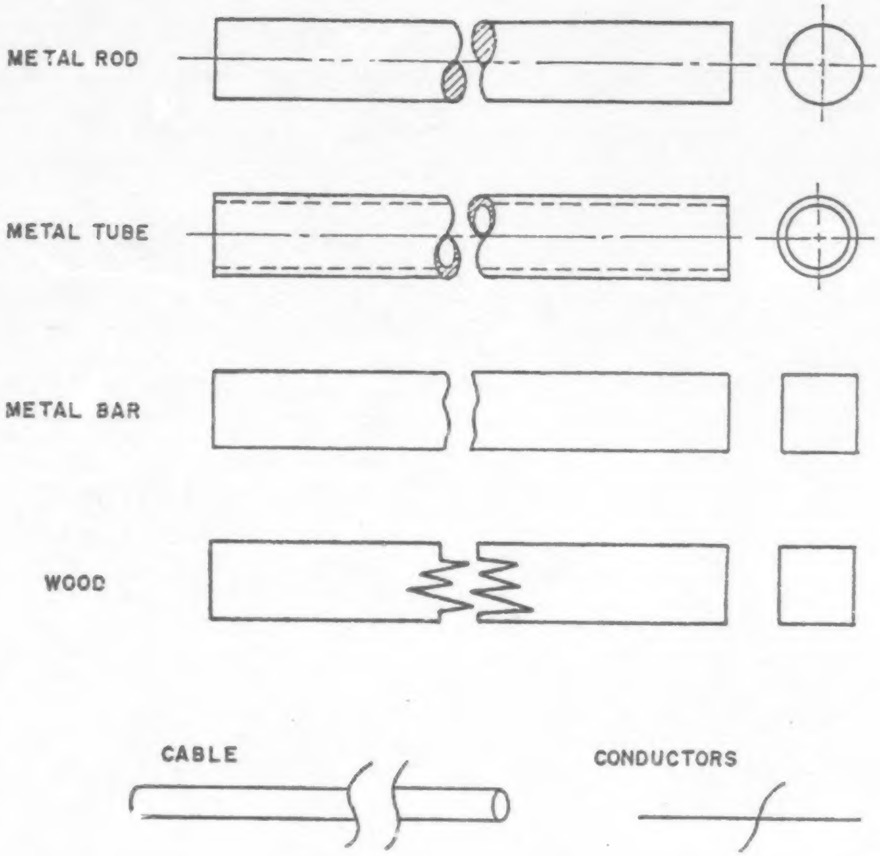


Figure 20. Break lines.

(10) Stitch lines. Stitch lines should be used to indicate stitching or sewing. This line consists of a series of dashes evenly spaced. Long lines of stitching may be indicated by a series of stitch lines connected by phantom lines. All stitch lines should be labeled (fig 21a).

(11) Outlines or visible lines. The outline or visible line should be used for all lines on the drawing representing visible lines on the object (fig 21b and 22).

(12) Datum lines. Datum lines are used to indicate the position of a datum plane and consist of a series of one long dash and two short dashes evenly spaced, unless the plane is established by another line such as an outline or extension (fig 21a).

(13) Cutting plane and viewing plane line. The cutting plane line should be used to indicate a plane or planes in which a section is taken. The viewing planes are used to indicate the plane or planes from which a surface or object is viewed (fig 21a and 22).

(14) Arrowheads. Arrowheads vary with the size of configuration and with the length to width ratio. This ratio is held to approximately 3 to 1; that is, the arrowhead is 3 times as long as it is wide. The arrowhead denotes the termination of a dimension and leader line with the tip ending on the line to which it is drawn (fig 22).

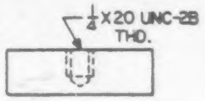
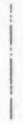
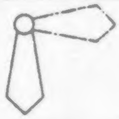
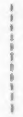
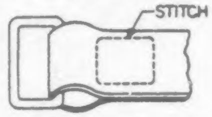
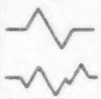
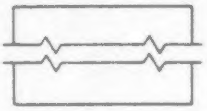
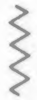
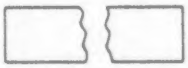
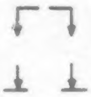
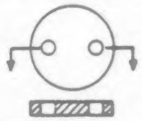
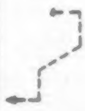
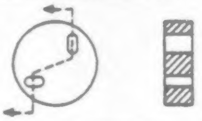
LINE CONVENTIONS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
LEADER		THIN LINE TERMINATED WITH ARROW-HEAD OR DOT AT ONE END USED TO INDICATE A PART, DIMENSION OR OTHER REFERENCE	
PHANTOM OR DATUM LINE		MEDIUM SERIES OF ONE LONG DASH AND TWO SHORT DASHES EVENLY SPACED ENDING WITH LONG DASH USED TO INDICATE: ALTERNATE POSITION OF PARTS, REPEATED DETAIL OR TO INDICATE A DATUM PLANE	
STITCH LINE		MEDIUM LINE OF SHORT DASHES EVENLY SPACED AND LABELED USED TO INDICATE STITCHING OR SEWING	
BREAK (LONG)		THIN SOLID RULED LINE WITH FREE-HAND ZIG-ZAGS USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL	
BREAK (SHORT)		THICK SOLID FREE-HAND LINES USED TO INDICATE A SHORT BREAK	
CUTTING OR VIEWING PLANE · VIEWING PLANE OPTIONAL		THICK SOLID LINES WITH ARROWHEAD TO INDICATE DIRECTION IN WHICH SECTION OR PLANE IS VIEWED OR TAKEN	
CUTTING PLANE FOR COMPLEX OR OFFSET VIEWS		THICK SHORT DASHES USED TO SHOW OFFSET WITH ARROW-HEADS TO SHOW DIRECTION VIEWED	

Figure 21a. Line characteristics and conventions.

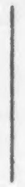
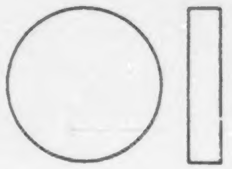
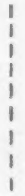
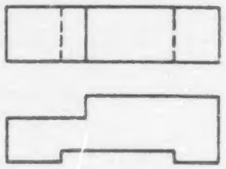
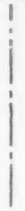
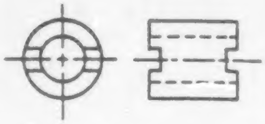
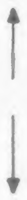
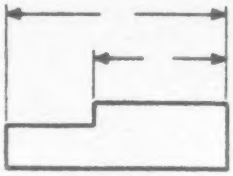
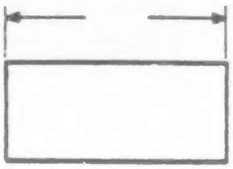
LINE CONVENTIONS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
VISIBLE LINES		HEAVY UNBROKEN LINES USED TO INDICATE VISIBLE EDGES OF AN OBJECT	
HIDDEN LINES		MEDIUM LINES WITH SHORT EVENLY SPACED DASHES USED TO INDICATE CONCEALED EDGES	
CENTER LINES		THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS	
DIMENSION LINES		THIN LINES TERMINATED WITH ARROWHEADS AT EACH END USED TO INDICATE DISTANCE MEASURED	
EXTENSION LINES		THIN UNBROKEN LINES USED TO INDICATE EXTENT OF DIMENSIONS	

Figure 21b. Line characteristics and conventions.

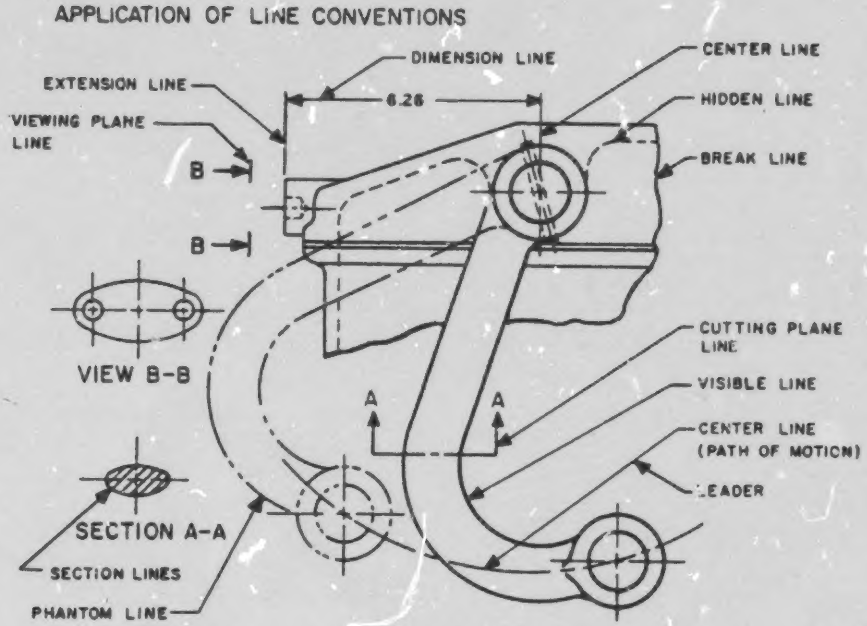

APPLICATION OF LINE CONVENTIONS
DIMENSION LINE
EXTENSION LINE
6.26
VIEWING PLANE LINE
B
B
CENTER LINE
HIDDEN LINE
BREAK LINE
VIEW B-B
CUTTING PLANE LINE
VISIBLE LINE
A
A
CENTER LINE (PATH OF MOTION)
LEADER
SECTION A-A
SECTION LINES
PHANTOM LINE

Figure 22. Line convention.

7. DIMENSIONING.

a. Definitions.

(1) Allowance. An allowance is a prescribed difference between the maximum clearance (positive allowance) or maximum interference (negative allowance) between such parts.

(2) Clearance. Clearance is the total space between mating parts.

(3) Dimension. A dimension is a numerical value expressed in appropriate units of measure. It is indicated on drawings in conjunction with lines, symbols, and notes to define the geometrical characteristics of an object.

(4) Dimensioning.

(a) Angular dimensioning. The angular dimensioning system is a method for indicating the position of a point, line, or surface by means of linear dimensions and angles, other than 90° angles.

(b) Rectangular dimensioning. The rectangular dimensioning system is a method for indicating distances, locations, and sizes by means of linear dimensions measured parallel to reference lines or planes which are perpendicular to each other.

(5) Eccentricity. Eccentricity is a condition where the axis of a particular feature is parallel to, but offset from, the axis of another feature; or where the axis of a rotating part mounted in an assembly does not coincide with the axis of the part about which it turns.

(6) Feature. Features are specific characteristics or component portions of a part, which may include one or more surfaces such as holes, screw threads, profiles, or rabbets.

(7) Fit. Fit is the general term used to signify the range of looseness or tightness which may result from the application of a specific combination of allowances or tolerances in the design of mating parts.

(a) Actual fit. The actual fit between two or more mating parts is the relation existing between them with respect to the amount of clearance or interference which is present when they are assembled.

(b) Clearance fit. A clearance fit is one having limits of size so prescribed that clearance always results when mating parts are assembled.

(c) Interference fit. An interference fit is one having limits of size so prescribed that an interference always results when mating parts are assembled.

(d) Transition fit. A transition fit is one having limits of size so prescribed that either a clearance or an interference may result when parts are assembled.

(8) Interchangeability. Interchangeability is a condition of design wherein any and all mating parts will assemble and function properly without the need for any part modification at assembly.

(9) Interference. Interference is the total amount of deformation required to force an internal member into a smaller external member.

(10) Limits. Limits are the maximum and minimum values prescribed for a specific dimension. Limits may be of size or of location depending upon the application.

(11) Typical. The term "typical," when associated with a dimension or feature means that this dimension or feature applies to the locations that appear to be identical in size and configuration. The tolerance stated for a dimension labeled "typical" also applies to each identical feature.

b. Fundamental dimensioning rules.

(1) Show enough dimensions so that the intended sizes, shapes, and locations can be determined without assuming any distances.

(2) State each dimension clearly so that it can be interpreted in only one way.

(3) Show the dimensions between points, lines, or surfaces which have a necessary and specific relation to each or which control the location of other components or mating parts.

(4) Select and arrange dimensions to avoid accumulations of tolerances that may permit various interpretations and cause unsatisfactory mating of parts and failures in use.

(5) Show each dimension only once except when necessary to clarify a section or view.

(6) When possible, dimension each feature in the view where it appears in profile or where its true shape appears.

c. Dimension lines. Dimensions that indicate sizes and positions are given as linear distances or as angles. They may be given with dimension lines and extension lines that show their direction and extent, or in the form of notes with leaders that direct them to a particular place on the drawing (fig 23).

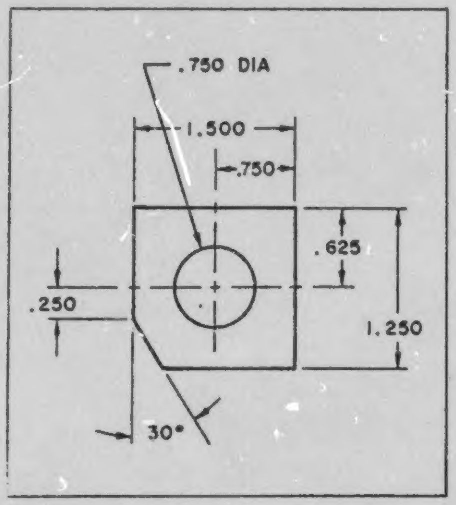

.750 DIA
1.500
.750
.625
.250
1.250
30°

Figure 23. Ways to indicate dimensions.

(1) A dimension line with its arrowheads shows the direction and extent of a dimension. Numerals are used to indicate the number of units of a measurement. If the numerals are in a single line, the dimension line should not be broken as shown in a of figure 24. If the numerals are in two lines, one may be placed above and the other below the line as shown in b of figure 24.

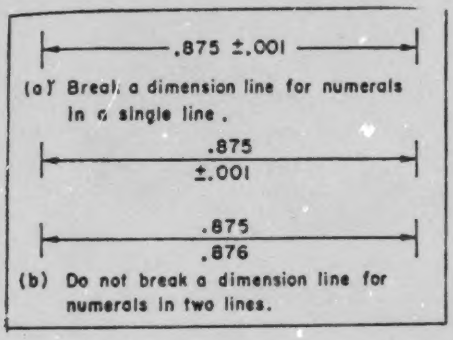

.875 ±.001
(a) Break a dimension line for numerals in a single line.
.875
±.001
.875
.876
(b) Do not break a dimension line for numerals in two lines.

Figure 24. Dimension lines.

92

(2) Dimension lines should be alined, if possible, and should be grouped for uniform appearance; however, where there are several parallel dimension lines, the numerals should be staggered to make them easier to read. An example of this staggering is shown in figure 25.

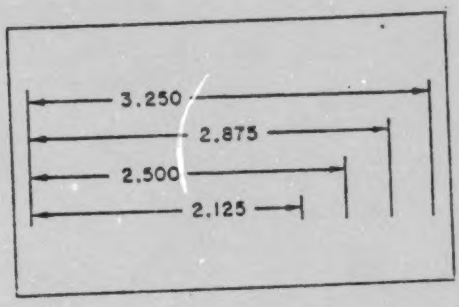


Figure 25. Numerals staggered for clarity.

d. Extension lines. It is usually undesirable to terminate dimension lines directly at lines that represent surfaces of the actual object portrayed by the drawing. To prevent this, extension lines are used to show where numerical or other expressions are intended to apply.

(1) An extension line that is drawn to an outline representing a surface should start with a visible gap from the outline and extend about 1/8 inch beyond the outermost dimension line (fig 26).

(2) Wherever possible, extension lines should neither cross one another nor cross dimension lines. To reduce crossing to a minimum, the shortest dimension line nearest the outline of the object should be drawn first and adjacent parallel dimension lines in order of their length, with the longest line being the outermost. Extension lines should not be broken when they cross other extension lines, dimension lines, or object lines. However, should an extension line cross a dimension line close to an arrowhead, a break in the extension line is recommended. An example of these breaks in extension lines is shown in figure 27.

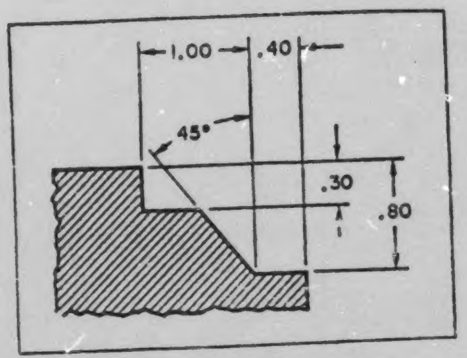


Figure 26. Extension lines.

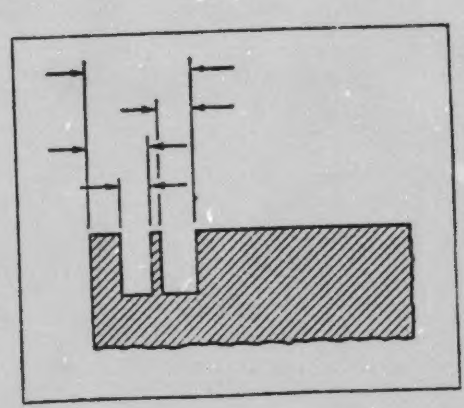


Figure 27. Breaks in extension lines.

OS 424, 3-P20

e. Locating round holes. Figures 28 through 33 illustrate the positioning of round holes by giving distances or distances and directions to the hole centers. These methods can also be used to locate round pins and other features of symmetrical contours.

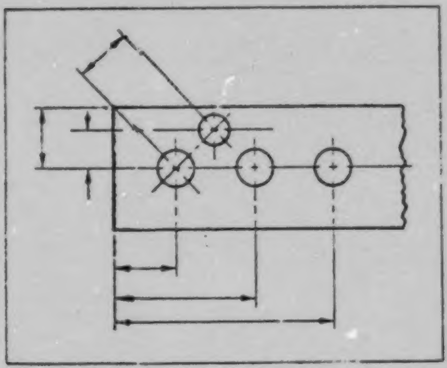


Figure 28. Locating round holes by linear distances.

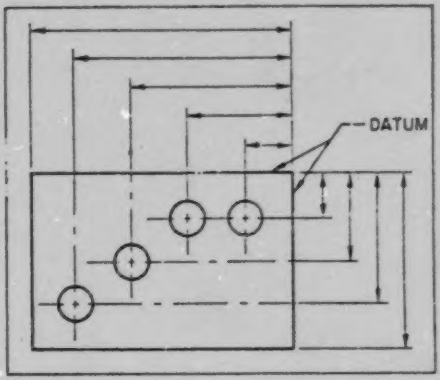


Figure 29. Dimensions from datums.

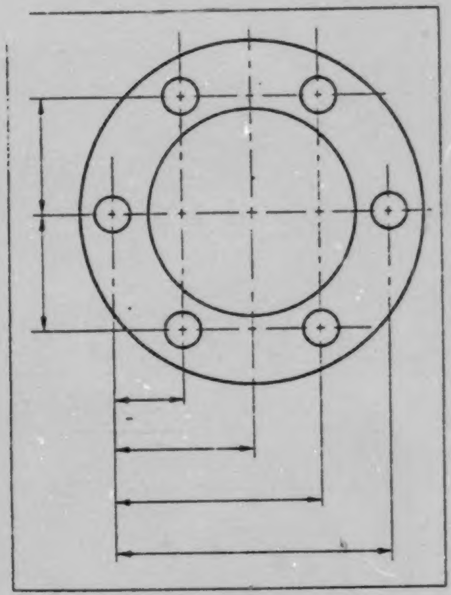


Figure 30. Locating round holes by rectangular coordinates.

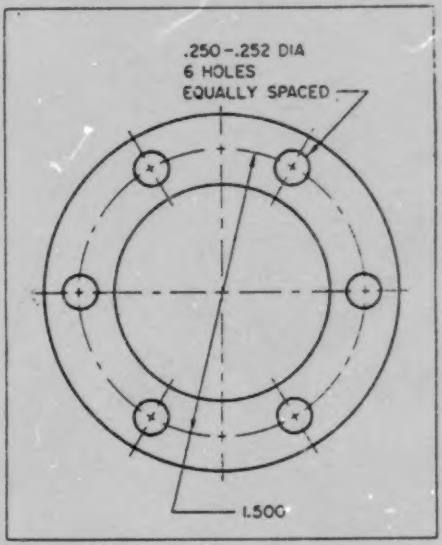


Figure 31. Locating holes on circles by radius or diameter and "EQUALLY SPACED."

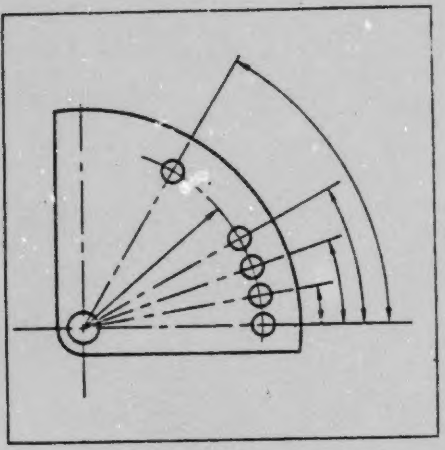


Figure 32. Locating holes on circle by angular dimensioning.

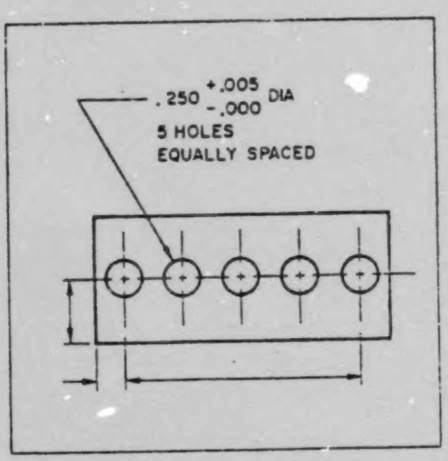

.250 $^{+.005}_{-.000}$ DIA
5 HOLES
EQUALLY SPACED

Figure 33. "EQUALLY SPACED" holes in a line.

f. Dimensioning a circular arc. A circular arc is dimensioned by giving its radius. Where space permits, a radius dimension line is drawn from the radius center, with the arrowhead ending at the arc and with the dimension between the arrowhead and the center. The numerical portion of the dimension should be followed by the abbreviation "R." Where space is limited, as for a small radius, a leader may be used. When it is inconvenient to place the arrowhead between the center of the radius and the arc, it may be placed outside the arc. The center of the radius may be indicated by a small cross to clarify the drawing. Where space does not permit showing the complete radius dimension line to scale, the line may be foreshortened. The portion of the dimension line ending in the arrowhead should be in the radial direction. Examples of this type of dimensioning are shown in figure 34.

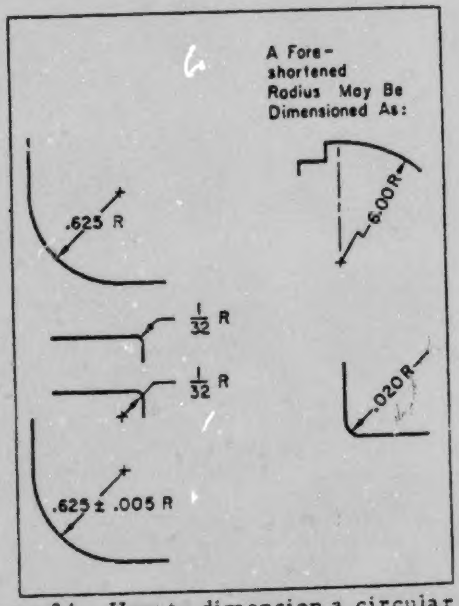

A Fore-shortened Radius May Be Dimensioned As:
.625 R
6.00 R
$\frac{1}{32}$ R
$\frac{1}{32}$ R
.020 R
.625 ± .005 R

Figure 34. How to dimension a circular arc.

8. TOLERANCES AND LIMITS.

a. Limits are the maximum and minimum values prescribed for a specific dimension. A tolerance represents the total amount by which a specific dimension may vary; thus, the tolerance is the difference between the limits.

b. A tolerance is expressed in the same form as its dimension; that is, the tolerance on a decimal dimension is expressed by a decimal to the same number of places, and the tolerance on a dimension written as a common fraction is expressed as a common fraction. Figures 35 and 36 illustrate five different methods of expressing tolerances.

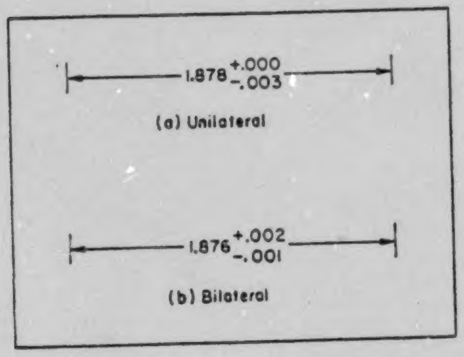


Figure 35. Giving a tolerance by a plus and minus figure.

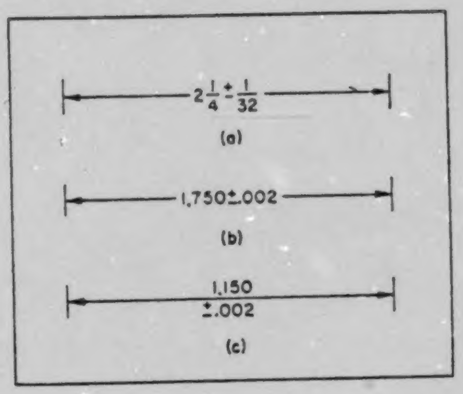


Figure 36. Using a combined plus and minus sign.

c. Numerals that indicate tolerances should be placed in one of the following ways:

(1) To the right and in line with the dimensional numerals (fig 36a and 36b).

(2) Below the dimension numeral with the dimension line between (fig 36c).

(3) To the right of the dimension numeral with the plus variation above the level of the dimension line and the minus variation below it. In this method, the dimension line is not drawn between the numerals indicating tolerances (fig 35).

d. All limits are considered to be absolute. Dimensional limits, regardless of the number of decimal places, are used as if they were continued with zeros. For purposes of determining conformance with limits, the measured value is to be compared directly with the specified value and any deviation, however small, outside the specified limiting values signifies nonconformance with the limits.

For example:

1.22 means 1.220—0

1.20 means 1.200—0

1.202 means 1.2020—0

1.200 means 1.2000—0

e. The symbols shown in figure 37 are used to state the geometric characteristics that are being toleranced. When the symbols are used, a positional or form tolerance should be stated by means of the feature control symbol illustrated in figure 38. The geometric characteristic symbol should be followed by the permissible tolerance and, in some cases, by the modifier Ⓜ or Ⓢ. The feature control symbol should be associated with the feature(s) being toleranced by one of the following methods:

(1) Adding the symbol to a note pertaining to the feature(s).

(2) Running a leader line from the feature(s) to the symbol.

(3) Attaching a side, end, or corner of the control symbol outline box to an extension line from the feature.

(4) Attaching a side or end of the box to the dimension line pertaining to the feature when it is cylindrical.

—	FLATNESS & STRAIGHTNESS
∠	ANGULARITY
⊥	PERPENDICULARITY
∥	PARALLELISM
◎	CONCENTRICITY
⌖	TRUE POSITION
○	ROUNDNESS
⌯	SYMMETRY
Ⓜ	(MMC) MAXIMUM MATERIAL CONDITION
Ⓢ	(RFS) REGARDLESS OF FEATURE SIZE

Figure 37. Geometric characteristic symbols and modifiers.

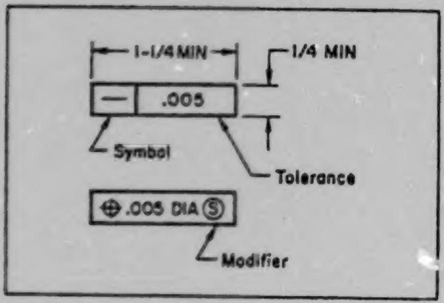

1-1/4 MIN
1/4 MIN
— .005
Symbol
Tolerance
⊕ .005 DIA Ⓢ
Modifier

Figure 38. Feature control symbol.

9. SYMBOLS.

a. Finish marks. Finish marks (✓) are used to indicate surfaces that must be finished by machining. This machining provides a better surface appearance and provides the fit with closely mated parts. In manufacturing, during the finishing process, the required limits and tolerances must be observed. Machined finishes should not be confused with finishes of paint, enamel, grease, chromium plating, and similar coatings.

b. Material symbols. Sectional views may be lined or crosshatched with a special line arrangement to indicate the basic kind of material. Some examples of these symbols are shown in figure 39; however, these symbols are intended for general identification only. They do not identify the specific types of materials. The particular type will be indicated elsewhere on the blueprint.

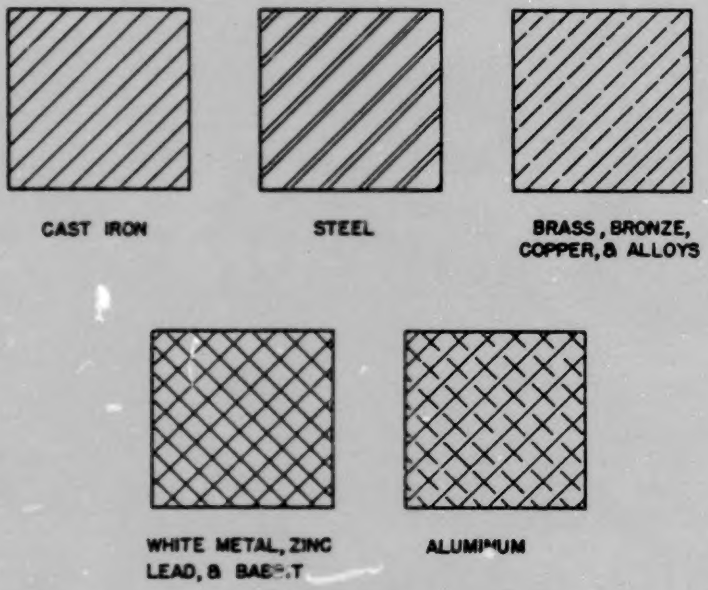

CAST IRON
STEEL
BRASS, BRONZE, COPPER, & ALLOYS
WHITE METAL, ZINC LEAD, & BABBIT
ALUMINUM

Figure 39. Examples of symbols to indicate kind of material.

c. Special symbols. There are some special symbols that may be encountered and a portion of these are shown in figure 40. There will be others found also; however, the following symbols are the basic ones. It is up to the individual to learn the additional symbols as they are applicable to the particular job assignment.

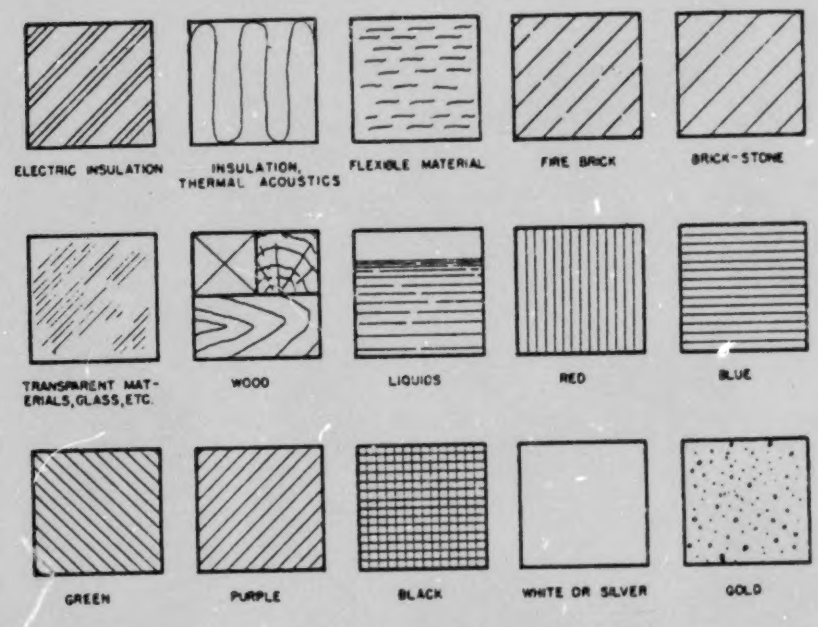

ELECTRIC INSULATION
INSULATION, THERMAL ACOUSTICS
FLEXIBLE MATERIAL
FIRE BRICK
BRICK-STONE
TRANSPARENT MATERIALS, GLASS, ETC.
WOOD
LIQUIDS
RED
BLUE
GREEN
PURPLE
BLACK
WHITE OR SILVER
GOLD

Figure 40. Special symbols.

10. SCALE.

a. The scale of the blueprint should be indicated in one of the spaces within the title blocks. It indicates the size of the drawing as compared with the actual size of the part. The scale is usually shown as 1" = 2", 1" = 12", and 1/2" = 1". The scale may also be indicated as full size, one-half size, and one-fourth size.

b. If a blueprint indicates that the scale is 1" = 2", each line on the print is shown one-half its actual length. A scale showing 3" = 1" indicates that each line on the print is three times its actual length.

c. A drawing should show an object or assembly to full size. When the full size views are not practical, the drawings should be made to reduced or enlarged scales. It is also desirable, wherever possible, to prepare detail drawings to the same scale as the pertinent subassembly and assembly drawings. In short, the scale is selected to fit the object being drawn and space available on a sheet of drawing paper.

d. It is important to remember that you never measure a drawing—always use the dimensions. This is due to the fact that the blueprints may have been reduced in size from the original drawing, and that there may be errors in the actual drawing. Then, too, paper stretches and shrinks as the humidity changes, thus introducing another source of error.

SECTION II. SKETCHING

11. INTRODUCTION.

a. Sketching is very important to an individual who works with any type of physical material. You will find that it is the best and, in some cases, the only method of conveying your ideas to other people. It is also helpful when you are planning or developing your own ideas.

b. There is no military standard for technical sketching. What information is either included on a sketch or omitted is left up to the man who makes the sketch. He will include as much information as he feels necessary to serve the purpose for which he makes the sketch. It should be remembered, however, that all of the information such as dimensions or notes should conform to the procedures as presented in the first section of this lesson.

c. Mechanical drawings are made with mechanical devices such as a pencil compass, triangles, and T-square. A sketch is usually thought of as being made freehand, although in practice it may be made on squared paper or with the help of a rule and pencil compass.

d. Usually a sketch is made from an object, but it can also be an "idea" sketch of something you are thinking about, or a combination of both. It can be drawn pictorially, so that it actually looks like the object, or it can be an orthographic sketch of the object with three different views, usually front, side, and top. It can be either an assembly sketch or a detail sketch. An assembly sketch, as the name implies, will show two or more parts fastened together to form a complete unit. A detail sketch will show, in detail, one single part of an assembly.

12. SKETCHING TOOLS.

a. Some of the value in technical sketching ability, in addition to the fact that it is an excellent way to present your ideas to someone else, lies in the fact that so few tools are necessary. If you have a stub of a soft pencil (HB or F) and a scrap of paper handy, you are ready to go. However, a pencil long enough to permit a relaxed but stable grip will improve your sketching. For most sketchings you hold the pencil exactly as you do when writing. If you are sketching a circle it may be easier to do so with the pencil below your hand and held against your four fingers with your thumb.

b. When erasing is required, the eraser at the end of some pencils is, of course, handy and satisfactory for limited use. The soft end of a pencil-and-ink eraser, however, is better, but artgum and pink pearl types of erasers are best; they will do a cleaner job of removing pencil lines from paper.

c. If you should use a pencil compass, the inexpensive kind costing about a quarter at stationery stores is all you need. Almost any kind or size rule can be used as a straightedge. As your ability to sketch improves, you may find that the compass and straightedge can be used less and less until they are no longer needed to produce neat and effective sketches quickly. This is the ideal situation which some men reach before others.

d. Just as preparing rough sketches without instruments saves time, the use of cross section paper saves more time. Cross section paper is especially useful when sketching to scale and is usually ruled into one-inch squares. These squares are then subdivided into one-eighth or one-tenth inch squares.

13. TECHNIQUE OF SKETCHING.

a. Hold the pencil from three-quarters to an inch from the point so that you can see what you are doing. Strive for a free and easy movement rather than a cramped finger and wrist movement.

b. In freehand pencil sketching, draw lines with a series of short strokes, instead of trying to draw each line with one stroke. Using short strokes, you can better control the direction of your line and the pressure of your pencil on the paper.

c. In sketching lines place a dot where you want the line to begin and one where you want it to end. In sketching long lines, place one or more dots between the end dots. Then swing your hand in the direction your line should go, and back again a couple of times before you touch your pencil to the paper. In this way, you get the feel of the line. Then use these dots to guide your eye and your hand as you draw the line.

d. Vertical lines are usually sketched downward on the paper. The same suggestions for using locating dots and free movement of the entire arm apply to vertical lines as they do to horizontal lines. Slanting lines may be drawn from either end toward the other.

e. Using only horizontal lines, vertical lines, and slanting lines, it is possible to make any number of complete and acceptable technical sketches, depending, of course, on the item or job to be sketched.

f. Keep your freehand sketch neat. To do this, first sketch your lines lightly. Lines which are not essential to the drawing can be sketched so lightly that it is not necessary to erase them. Essential lines can be darkened by running the pencil over them with more pressure after they have been first drawn lightly.

g. Technical sketches frequently include many circles or arcs. You don't need to be gifted with artistic talent to draw good circles if you will follow these suggestions.

(1) In A of figure 41 observe how the pencil is held beneath the four fingers with the thumb. This grip tends to produce a "soft" or "easy" motion for sketching large circles or curves and also makes it possible to sketch small circles as shown in figure 41B and C. You will notice in figure 41B that the second finger rests at the center of the circle and forms the pivot about which the pencil lead can swing. The distance from the finger tip to the pencil lead determines the radius of the circle. To draw smaller circles a somewhat different grip on the pencil is necessary, as shown in C of figure 41, but the principle is the same. Figure 41 shows the proper way to grip the pencil; figure 42 shows how to draw the circles using these grips.

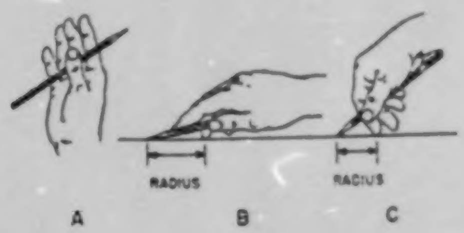


Figure 41. Circles and arcs.

(2) As shown at A in figure 42, the first step in sketching either large or small circles with the holds shown in the previous figure is placing the second finger on the paper at the center of the proposed circle. Then, with the pencil lightly touching the paper, use the other hand to rotate the paper to give you a circle that may look like the one in figure 42B. To correct the slight error of closure shown in C, erase a substantial section of the circle and correct it by eye as shown at the right. You now have a complete and round circle, but only with a very light line which must be made heavier. Do this as shown in B. Notice that you do NOT PIVOT on the second finger during this step. You rest your hand on its side, keep it within the circle, and trace over the light line with your hand pivoting naturally at the wrist. As you work around the circle in this way, rotate the paper counterclockwise so that your hand can work in the most natural and easy position as shown. With the smaller circles you cannot, of course, work with your hand within the circle, but the same general approach can be used with success.

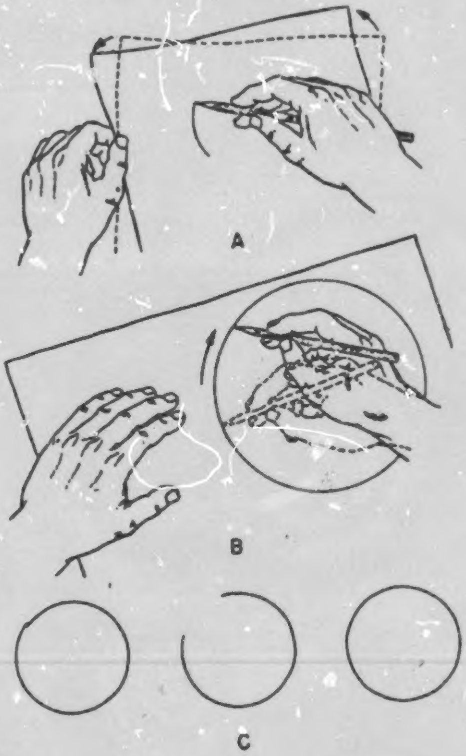


Figure 42. Steps in sketching a circle.

(3) Figure 43 shows another method of drawing circles and curves using straight lines as construction lines. First, draw two straight lines crossing each other at right angles as in figure 43A. The point where they cross will serve as the center of the circle. The four lines radiating from this center will serve as the radii of the circle. You can use a piece of marked scrap paper to measure an equal distance on each radius from the center. Sketch a square, with the center of each side passing through

the mark defining a radius (fig 43B). Now sketch in your circle, using the angles of the square as a guide for each arc.

(4) In figure 43C and D, four lines, instead of two, are sketched crossing each other. The radii are measured as in constructing the other circle, but the square is not added before the circle is drawn.

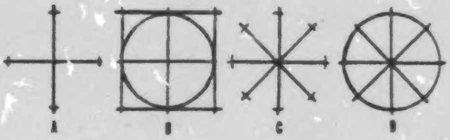


Figure 43. Sketching circles.

(5) Figure 44 shows a convenient way of sketching arcs, tangent arcs, and curves by blocking them in with straight lines.

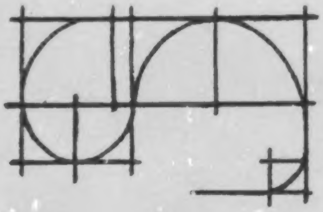


Figure 44. Sketching curves.

14. CONSTRUCTION LINES. When you are drawing a part, such as that shown in figure 45, don't start at one corner and draw it detail by detail and expect it to come out with the various elements in correct proportion. It is better to block in the overall shape of the object first (fig 45A). Then draw light guidelines at the correct angle for various outlines of the object (fig 45B and C). Finish the sketch by first making an outline of the object, and then drawing in the details as shown in figure 45D.

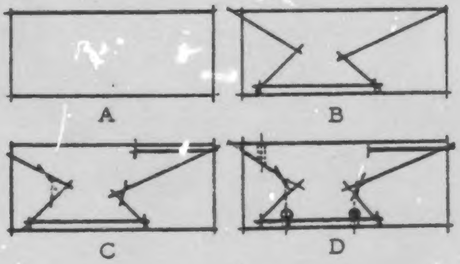
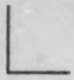


Figure 45. The use of construction lines in sketching an object.

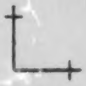
15. CURVES OR ARCS CONNECTING STRAIGHT LINES.

a. Some people have developed the ability to sketch curves and straight lines without the use of guidelines. Many of us, however, through lack of interest or practice, require some basic guidelines to sketch curves properly.

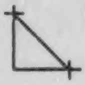
b. Probably one of the best methods to sketch curves, connected to straight lines, can be accomplished by following the 6 basic steps illustrated and explained below:



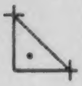
(1) Intersect a vertical and horizontal line, lightly.



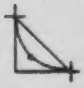
(2) Mark off on the horizontal and vertical lines the same distance from the intersection (corner).



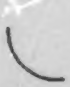
(3) Draw a light diagonal line through the two points marked.



(4) Place an "X" or a dot (.) in the exact center of the triangle formed.



(5) Start your curve from one point of the triangle (preferably on the vertical line) touching the "X" or dot and ending at the other point of the triangle.



(6) Erase all the unnecessary guidelines and darken the curve and necessary adjoining straight lines.

A little practice using the 6 steps mentioned above should improve your ability to sketch curves properly.

16. **SKETCHING THREE-VIEW DRAWINGS.** To make a working sketch, you should first choose a clean sheet of plain or ruled paper. Estimate the size the sketch should be, and select the views which will give the best picture of the object. Then sketch the three views, leaving adequate space between them for dimensions. When you sketch the views:

a. Sketch in center lines, as shown in figure 46A.

b. Lightly block in the views.

c. Sketch in the outlines alining them as in figure 46B.

d. Sketch the details on the surface of the views.

e. Darken the lines of the finished sketch.

104

f. Use an artgum or a kneaded eraser to erase the construction (guide) lines which are no longer necessary, and touch up the necessary lines which you may have inadvertently erased.

g. Sketch all necessary extension and dimension lines.

h. Letter in the dimensions (fig 46C).

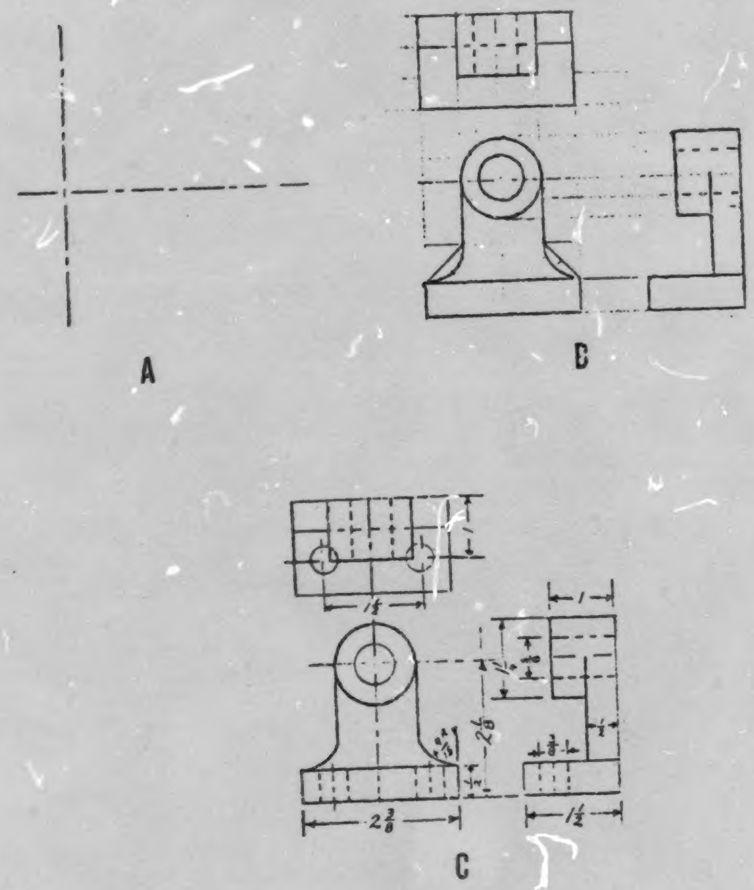


Figure 46. Progress of a working sketch.

17. ISOMETRIC SKETCHING.

a. Not everyone is naturally gifted with the ability to sketch or draw objects exactly as they should look. But everyone, with the aid of some basic rules, can help himself acquire the ability to put on paper that which he may have in mind or may be observing. A decent looking isometric sketch can be drawn by adhering to a few simple, basic rules or principles.

b. Select a position (view) that will show the object to the best advantage. You will know what you want included in your sketch, so move either the object or yourself until you can actually see everything you want to show. If the object is something you have "in mind" or if you intend to sketch an isometric view from an orthographic drawing, you will have to visualize the object and assume a viewing position. Remember in making your isometric sketch, you start by sketching 3 isometric axes 120° apart, using two angles of 30° and a vertical axis of 90°.

c. Figure 47 shows in a step-by-step procedure the technique used in making an isometric sketch of a wooden rectangular block measuring 1-1/2 x 3 x 5 inches.

d. The first step is to sketch the three isometric axes, as mentioned earlier. The second step is to mark off the 1-1/2 inches for height on the vertical axis, the 3-inch width along the left axis, and the 5-inch length along the right axis. The third step is to draw two vertical lines 1-1/2 inches high, starting with the marks on the right and left axis. The fourth step is to sketch parallel lines from each of the marks on the sketch. Note that the lines that are parallel on the object are parallel on the sketch. The fifth step is to dimension the sketch. The dimensions on an isometric sketch are placed parallel to the ends of edges. The final step is to check the sketch for completeness and accuracy.

e. It is important to remember that circles appear in the isometric as ellipses and that the major axis of the ellipse is always at right angles to the shaft or rotation axis. Thus, the minor axis coincides with the shaft or rotation axis.

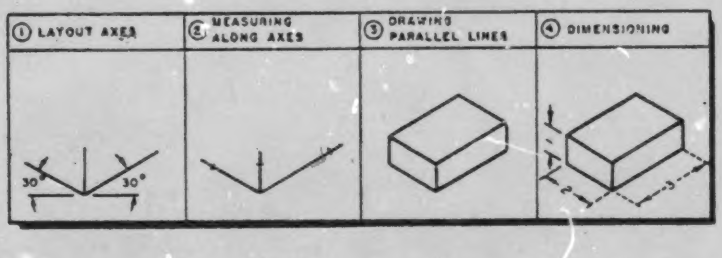


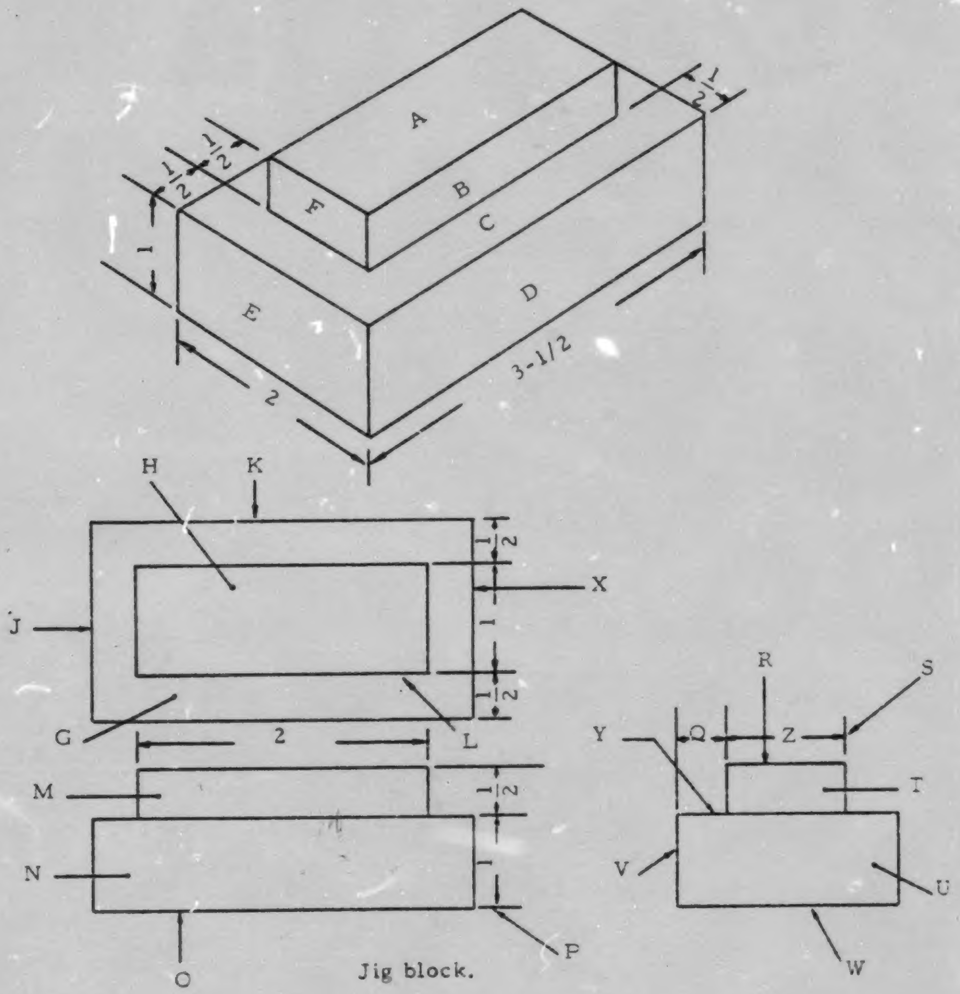
Figure 47. Steps in sketching an isometric drawing.

SECTION III. CONCLUSION

18. SUMMARY. The primary types of mechanical drawings used for blueprints have been described with emphasis on orthographic drawings from which most working blueprints are reproduced. This lesson has endeavored to teach you how to read blueprints through visual identification of lines, symbols, etc; how to perform layout on stock from blueprints; and how to draw a sketch of an object that can be interpreted by an engineer or draftsman in order to produce a mechanical drawing.

EXERCISE

__Note.__ - Questions 36 through 45 apply to the drawing of the jig block.


A
B
C
D
E
F
1/2
1/2
1/2
1
2
3-1/2
H
K
1/2
X
1
1/2
J
G
L
2
M
1/2
N
1
O
P
R
S
Y
Q
Z
T
V
U
W

Jig block.

36. What letter in the front view is represented by surfaces "F," "B," and "A" in the isometric drawing?

   a. M
   b. N
   c. O

37. What letters in the orthographic views represent surface "A" of the isometric drawing?

    a. G and H
    b. M and L
    c. H and R

38. What is the dimension "Z?"

    a. 1/2
    b. 1
    c. 1-1/2

39. What letters in the orthographic views represent surface "C" of the isometric drawing?

    a. G and Y
    b. J and T
    c. R and H

40. What is the overall height of the jig block?

    a. 1
    b. 1-1/2
    c. 2

41. What surface on the side view is represented by "E" in the isometric drawing?

    a. T
    b. U
    c. N

42. What is the dimension of "Q" in the side view?

    a. 1/2
    b. 1
    c. 1-1/2

43. What letters denote extension lines?

    a. V and W
    b. Q and Z
    c. P and S

44. What is the overall length of the jig block?

    a. 1
    b. 2
    c. 3

45. What letter in the front view denotes an outline or visible line?

    a. M
    b. N
    c. O

46. Which type of drawing is NOT considered to be a pictorial?

    a. Orthographic
    b. Perspective
    c. Isometric

47. What type of drawing is most commonly used in making freehand sketches?

    a. Orthographic
    b. Perspective
    c. Isometric

48. What type view is used to indicate alternate positions of parts of the item drawn?

    a. Auxiliary
    b. Exploded
    c. Phantom

49. Which type of sectional view shows the inner structure of a small area by removing the outside surface.

    a. Broken out section
    b. Revolved section
    c. Removed section

50. Which type fit is described as one having limits of size so prescribed that either a clearance or an interference may result when parts are assembled?

    a. Actual
    b. Transition
    c. Clearance

51. A circular arc is dimensioned by giving its

    a. diameter.
    b. length.
    c. radius.

52. The total amount by which a specific dimension may vary is known as its

    a. tolerance.
    b. variance.
    c. limit.

53. What does the symbol (⊙) indicate?

    a. Concentricity
    b. Roundness
    c. True position

54. What type of surface finish is indicated by the symbol (✓)?

a. Chromium plated
b. Machined
c. Greased

55. How far above the horizontal should the two outside isometric axes be sketched?

a. 30°
b. 60°
c. 90°

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 424. . . . . .Machine Shop Practice

Lesson 4 . . . . .Handtools, Measuring Instruments, and Basic Metalworking Machines

Credit Hours . . . . .Four

Lesson Objective . . . . .After studying this lesson you will be able to:

1. Identify and describe the uses and care of handtools.
2. Use measuring instruments common to machine shop practice.
3. Discuss the characteristics and uses of the basic metalworking machines to include hand and bench grinders, portable electric drills, drill presses, and portable hacksawing machines.

Text .Attached Memorandum.

Materials Required . . . . .None

Suggestions . . . . .Visit an industrial plant or technical or vocational high school and observe the scope of this lesson.

STUDY GUIDE AND ATTACHED MEMORANDUM

SECTION I. HANDTOOLS

1. INTRODUCTION. The following paragraphs discuss some of the more common handtools used by machinists. Additional coverage will be provided concerning the care and use of these handtools. As your knowledge of these tools increases, so will the proficiency of your shop. The job that will leave your shop will be of the highest quality because of the correct maintenance supervision given to the equipment under your control. Tools are one of man's greatest assets. The proper use of them makes all jobs easier. Of all tools, however, the most valuable and versatile is man's own hands. The skill of the hands can be increased and its power multiplied by the use of an endless variety of other tools that man has been designing and improving since the beginning of time. Those who use tools all through life should acquire a great deal of pride in the ability to use them well.

2. MACHINIST'S HAMMERS. Machinist's hammers are used primarily by people who work with metal or around machinery, and may be divided into two classifications: hard-face and soft-face.

a. Hard-face hammers.

(1) The hard-face hammer is made of forged tool steel. The best general purpose machinist's hammer is the ball-peen hammer (fig 1). The flat end of the head is called the face and is used for most of the hammering jobs you will have. The other end of the hammer is called the peen and is smaller in diameter than the face. It is, therefore, useful for striking areas that are too small for the face to enter. The peen is also useful for bradding rivets.

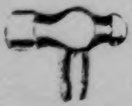


Figure 1. Machinist's ball peen.

(2) Ball-peen hammers are made in different weights, usually 4, 6, 8, and 12 ounces, and 1, 1-1/2, and 2 pounds. For most work a 1-1/2-pound and a 12-ounce hammer will suffice. However, a 4- or 6-ounce hammer will often be used for light work. There are variations of the peening hammer such as the cross-peen and the straight-peen (fig 2 and 3).

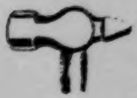


Figure 2. Machinist's cross peen.

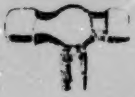


Figure 3. Machinist's straight peen.

b. Soft faced hammers. Wooden-handled, soft faced hammers (fig 4, 5, and 6) are used for striking heavy blows where the steel faced hammers would bruise or mar the surface of the work. The soft faces are made of rubber, wood, rawhide, copper, lead, or plastic, and the head may vary in weight from 6 ounces to 6 pounds. The Army Supply System issues a 3-pound copper hammer and several inserted plastic face hammers. The plastic face hammers are supplied with two soft, two medium, two tough, and two nylon replaceable faces.

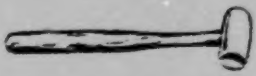


Figure 4. Copper hammer.

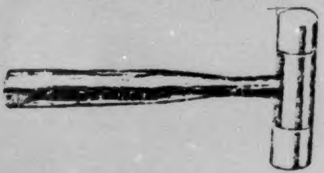


Figure 5. Plastic face hammer.

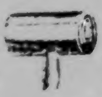


Figure 6. Rawhide mallet.

c. Correct use of hammers.

(1) Simple as the hammer is, there is a right and wrong way of using it (fig 7). The most common fault is holding the handle too close to the head. This is known as choking the hammer and reduces the force of the blow. It also makes it harder to hold the head in an upright position. Except for light blows, hold the handle close to the end to increase the lever arm and produce a more effective blow. Try to hit the object with the full face of the hammer. Hold the hammer at such an angle that the face of the hammer and the surface of the object being hit will be parallel. This distributes the force of the blow over the full face and prevents damage to both the surface being struck and the face of the hammer.

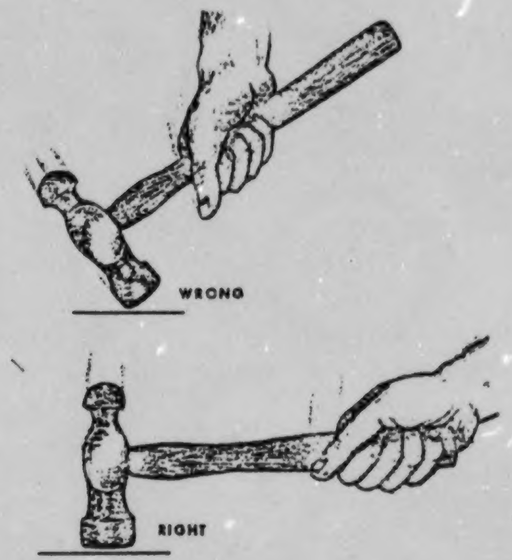


Figure 7. Right and wrong way to use a ball-peen hammer.

(2) Never strike a hardened steel surface with a hammer. This misuse is a serious safety hazard. Small pieces of sharp, hardened steel may break from the hammer and also from the hardened steel. Besides causing damage to the work and/or the hammer, a serious eye injury may result.

(3) Do not use a hammer handle for bumping parts in assembly, and never use as a pry bar. Such abuses will cause the handle to split, and a split handle can produce bad cuts or pinches. When a handle splits or cracks, do not try to repair it by binding with string or wire. Replace it.

d. Maintenance of striking tools. Hammers, sledges, or mallets should be cleaned and repaired, if necessary, before they are stored. Hammer and sledge faces should be free from oil or other material that would cause the tool to glance off nails, spikes, or stakes. The hammer heads should be dressed to remove any battered edges. Inspect the handles of striking tools and make sure they are secure to the head and do not have any cracks or splinters. Never leave a wooden or rawhide mallet in the sun, as it will dry out and may cause the head to crack. A light film of oil should be left on the mallet to maintain a little moisture in the head.

3. WRENCHES.

a. General.

(1) A wrench is a basic tool that is used to exert a twisting force on boltheads, nuts, and studs. The special wrenches designed to do certain jobs are, in most cases, variations of the basic wrenches that will be described in this section.

(2) The size of any wrench used on boltheads or nuts is determined by the size of the opening between the jaws of the wrench. The opening of a wrench is manufacturered slightly larger than the bolthead or nut that it is designed to fit. Hex-nuts (six sided) and heads are measured across opposite flats. A wrench that is designed to fit a 3/8-inch nut or bolt usually has a clearance of from 5 to 8 thousandths of an inch. This clearance allows the wrench to slide on and off the nut or bolt with a minimum of "play." If the wrench is too large, the points of the nut or bolthead will be rounded and destroyed.

b. Open end wrenches. Open end wrenches (fig 8) are usually double ended, although some have a single opening. These wrenches are forged from chrome-vanadium steel and heat treated. The size of the opening between the jaws determines the size of the open end wrench. For example, a wrench with a 1/2-inch opening in one end and a 9/16-inch opening in the other end is called a 1/2 by 9/16 wrench. The size of each opening is usually stamped on the side of the wrench. Open end wrenches are made in many different sizes. Wrench sizes range upward in steps of 1/32 inch, starting with 5/32 inch up to 1-3/4 inches. The common open end wrench is made with the ends at an angle of 10° to 23° to the body of the wrench so that the user can work in close quarters. Other special open end wrenches may have the ends at an angle of 45°, 60°, 75°, or 90°, or a combination of two angles. The length of the wrench is determined by the size of the opening, since the lever advantage of the wrench is proportional to its length; wrenches with larger openings are made longer and heavier to increase leverage and strength.

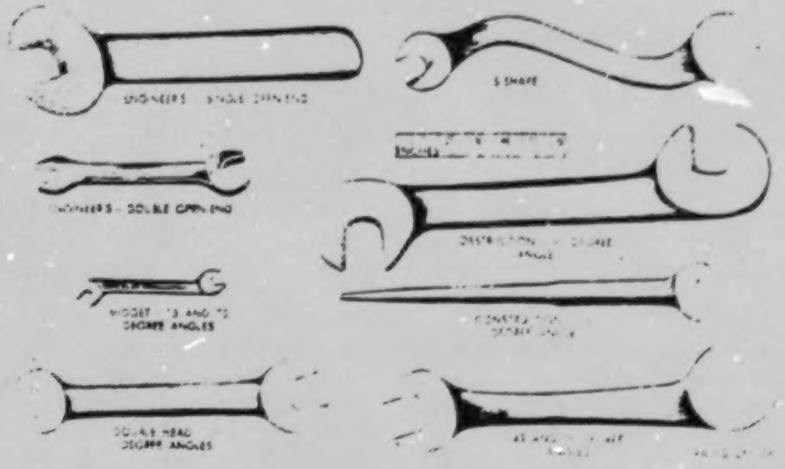


Figure 8. Open end wrenches.

c. **Box end wrenches.**

(1) Box end wrenches (fig 9) have either 6, 8, 12, or 16 points inside the head. The number of points determine the strength of the head. Six and 8 point wrenches are used for heavy duty, 12 for medium duty, and 16 for light duty work. The 12 point box end wrench is the most common and can be used with a minimum swing of 30°.

(2) There is little chance of the box end wrench slipping off the nut when the proper size wrench is used. Because the sides of the "box" opening are so thin, this wrench is suitable for turning nuts which are hard to get at with an open end wrench. The offset box end wrench is especially useful in this respect.

(3) There is one disadvantage to using box end wrenches. You lose time if you use it to turn the nut all the way off the bolt once it is broken loose. You must lift the wrench completely off the nut after each pull, then place it back on in another position. The only time this procedure is not necessary is when there is room to spin the wrench in a complete circle.

(4) After a tight nut is broken loose, it can be unscrewed much more quickly with an open end wrench than with a box wrench. This is where a combination box-open-end wrench comes in handy. You can use the box end for breaking nuts loose or for snugging them down, and the open end for faster turning. For heavy-duty work, there are long-handled, single, box end wrenches. They are made only in the larger sizes and you can apply all the pressure you need.

(5) The correct use of open end and box end wrenches can be summed up in a few simple rules, most important of which is to be sure that the wrench properly fits the nut or bolthead. When you have to pull hard on the wrench, as in loosening a tight nut, make sure the wrench is seated squarely on the flats of the nut. PULL on the wrench—DO NOT PUSH. Pushing a wrench is a good way to skin your knuckles if the wrench slips or the nut breaks loose unexpectedly. If it is impossible to pull the wrench, and you must push, do it with the palm of your hand and hold your palm open.

(6) Only actual practice will tell you if you are using the right amount of force on the wrench. The best way to tighten a nut is to turn it until the wrench has a firm, solid "feel." This will turn the nut to proper tightness without stripping the threads or twisting off the bolt. This "feel" is developed by experience alone. Practice until you have mastered the "feel."

(7) Hammering on wrenches is strictly taboo—with one exception. There is a special type of box wrench made strong and heavy so that you can hammer on it. The handle is short and has a steel pad on which the hammer blows are struck. This wrench is known as a "slugging" or "striking" wrench. Never place a piece of pipe over the handle of a wrench to increase leverage. This practice will damage the wrench and/or the nut or bolt that you are trying to tighten or loosen.

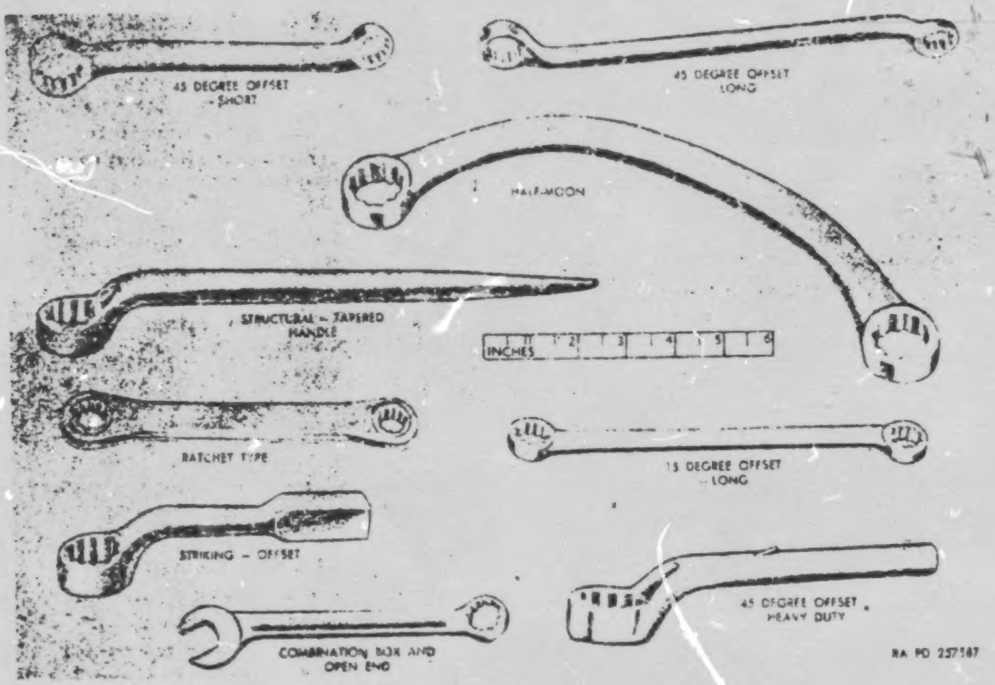

45 DEGREE OFFSET
- SHORT
45 DEGREE OFFSET
LONG
HALF-MOON
STRUCTURAL - TAPERED HANDLE
INCHES 1 2 3 4 5 6
RATCHET TYPE
15 DEGREE OFFSET
- LONG
STRIKING - OFFSET
45 DEGREE OFFSET
HEAVY DUTY
COMBINATION BOX AND
OPEN END
RA PD 257587

Figure 9. Box and combination wrenches.

d. Adjustable wrenches.

(1) Single open end wrench. The single open end adjustable wrench (fig 10) is similar in shape to the fixed end nonadjustable open end wrench, but has one adjustable jaw and one stationary jaw. The adjustable end wrenches issued by the Army Supply System have 1-3/8- to 2-7/8-inch jaw openings and are 24 inches long. A knurled nut is rotated to bring the movable jaw up to fit the nut or bolthead.

(2) Auto and monkey wrench. The auto and monkey wrenches (fig 10) are similar in design. They are of sturdy construction and are made to fit a wide range of nuts and bolts. They are designed principally for turning odd sized nuts or bolts which the open end, box, or socket wrenches will not fit, and when work requires a sturdy wrench.

(3) Pipe. The adjustable pipe wrench (fig 10) has two jaws that are not parallel. The outer jaw, which is adjustable, is made with a small amount of play that provides a tight grip on the pipe when the wrench is turned in the direction of the movable jaw. This is the only wrench which will take a bite on round objects. The jaws always leave marks on the work and should never be used on nuts or bolts, unless the corners have been rounded so that you cannot turn it with another type of wrench.

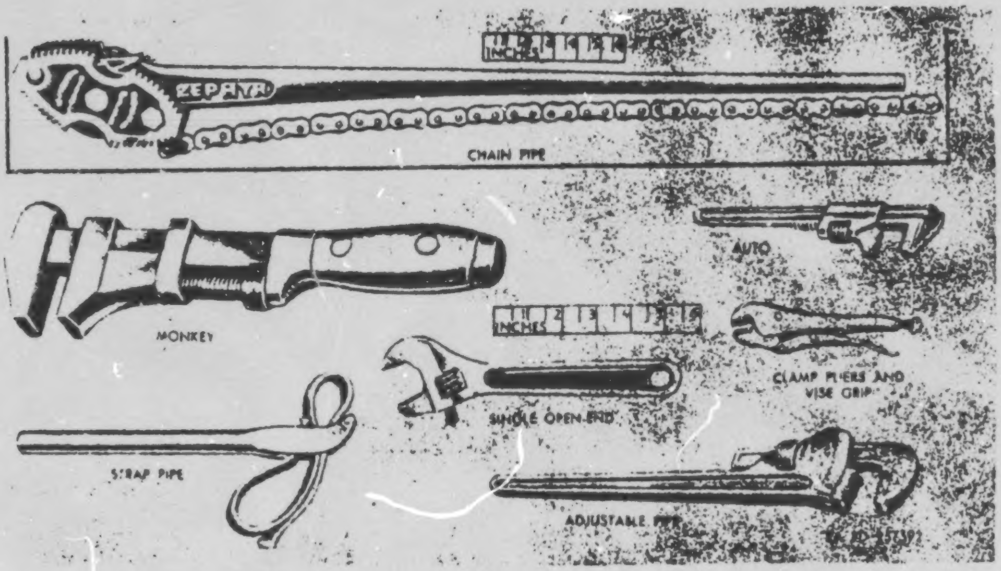


Figure 10. Adjustable wrenches.

e. Socket wrenches. The common socket wrench (fig 11 thru 14) is boxlike and made as a detachable socket for various types of handles. A socket wrench set usually consists of various sized sockets, a ratchet, a sliding tee bar, a speeder, a speed tee, a ratchet adapter, a nut spinner 4-3/8-inch drive handle, and extensions.

(1) Socket wrenches have two openings—one a square hole which fits the handles and the other a circular hole with notched sides to fit the bolt or screw head or nut to be turned. The square hole is made 1/4, 3/8, 1/2, 3/4, or 1 inch in diameter; each must be driven with the matching drive or speeder handle. The notched opening of the socket may have 6, 8, or 12 points.

(2) Socket wrenches are the fastest wrenches to use, since the ratchet handle permits the socket to remain on the nut or bolt and the handle does not have to be removed from the socket for turning. Socket wrenches are sized from 5/32 to 3-1/8 inches in steps of 32ds, 16ths, or 8ths of an inch. Some socket wrenches are not detachable and are of one-piece construction, such as the four-way socket wrench and the 90° offset handle. Other socket wrenches are of the screwdriver type, having a 6 pointed or a square socket. These may be straight or offset and have a T-type or regular screwdriver handle.

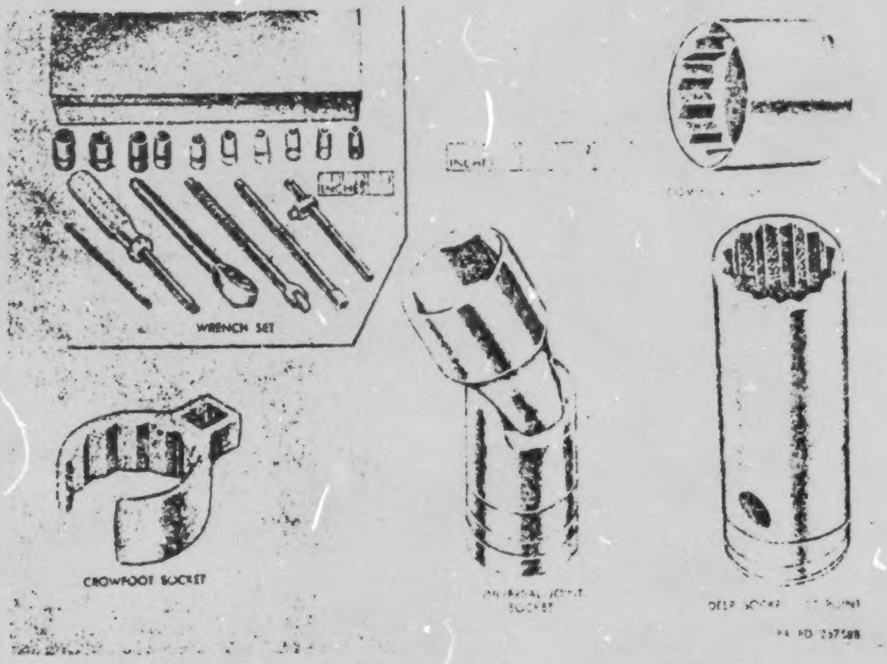

INCHES
WRENCH SET
INCHES
CROWFOOT SOCKET
UNIVERSAL JOINT SOCKET
DEEP SOCKET
RA PD 257588

Figure 11. Socket and crowfoot wrenches.

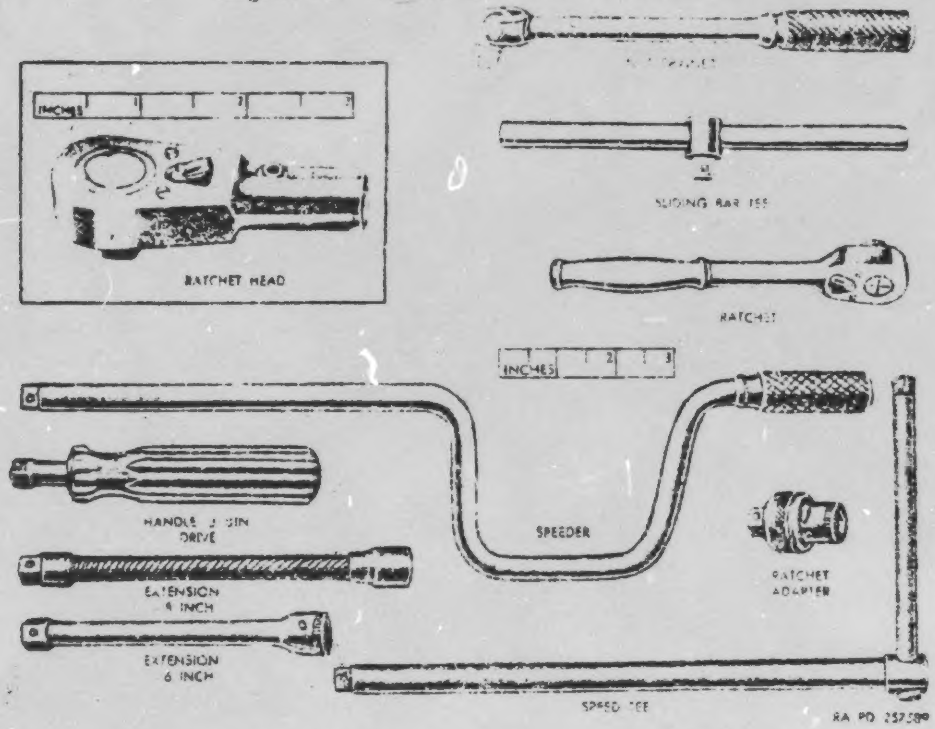

INCHES
RATCHET HEAD
SLIDING BAR TEE
RATCHET
INCHES
HANDLE DRIVE
SPEEDER
EXTENSION INCH
RATCHET ADAPTER
EXTENSION 6 INCH
SPEED TEE
RA PD 257589

Figure 12. Socket wrench ratchets, handles, and extensions.

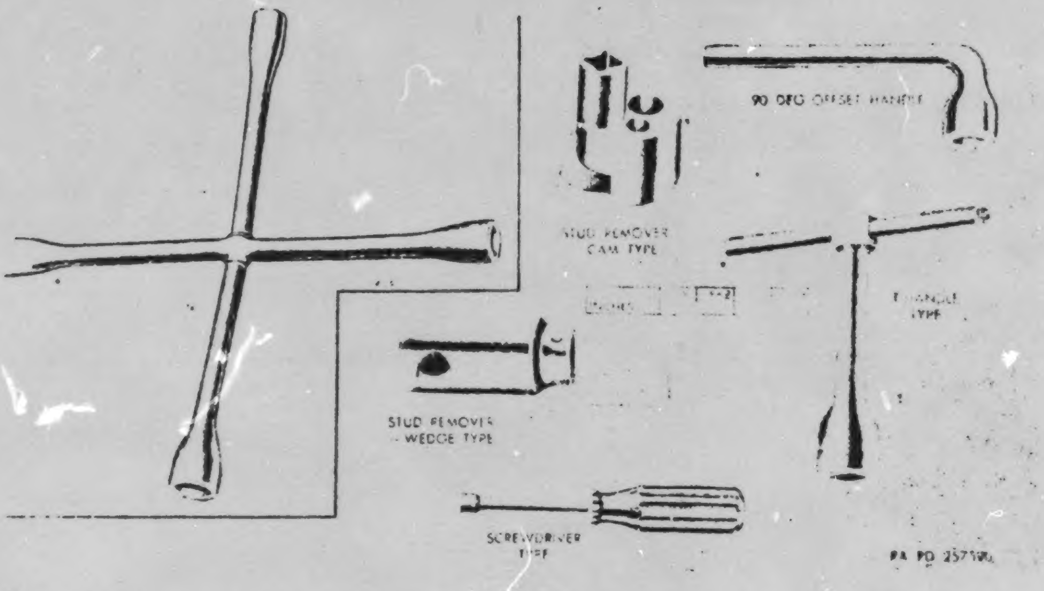
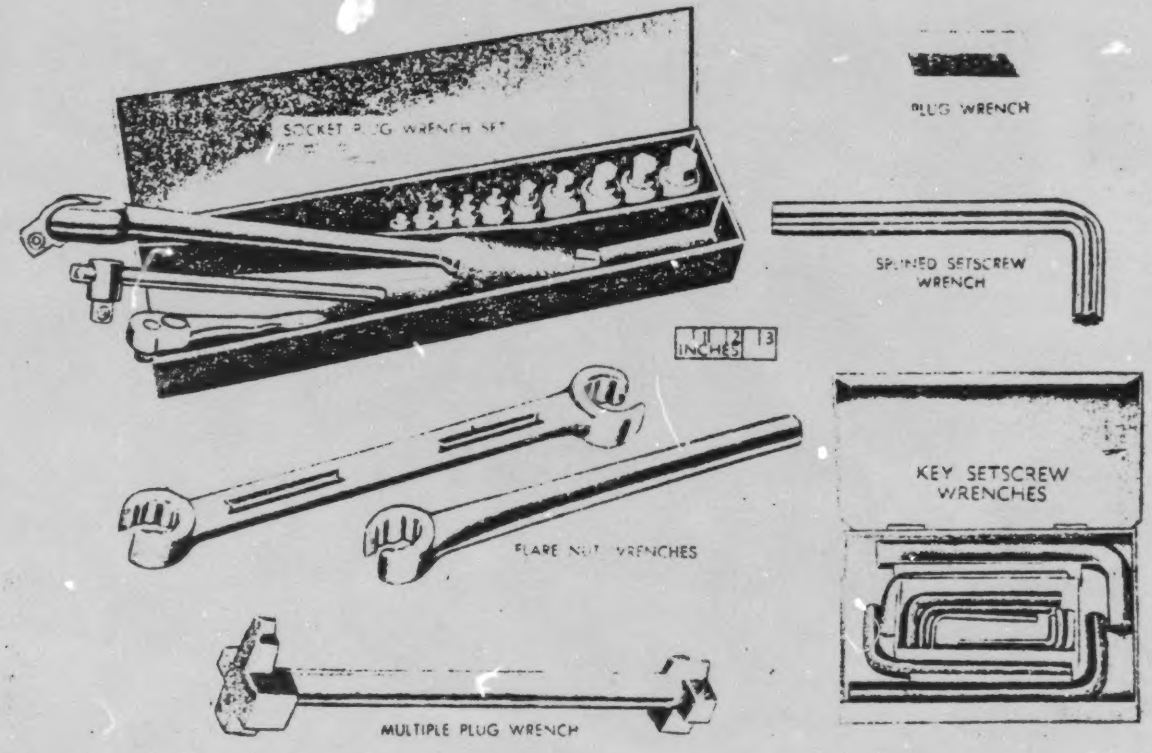

90 DEG OFFSET HANDLE
STUD REMOVER CAM TYPE
INCHES
T-HANDLE TYPE
STUD REMOVER - WEDGE TYPE
SCREWDRIVER TYPE
RA PD 257590

Figure 13. Special socket wrenches.


SOCKET PLUG WRENCH SET
PLUG WRENCH
SPLINED SETSCREW WRENCH
1 2 3
INCHES
KEY SETSCREW WRENCHES
FLARE NUT WRENCHES
MULTIPLE PLUG WRENCH

RA PD 257591

Figure 14. Setscrew, plug, and flare nut wrenches.

(3) Two types of stud remover sockets are available that are used with any 3/4-inch square drive socket wrench handle. One type has an eccentric cam which grips soft or hardened studs. The driving shank extends through both sides of the housing to provide a bearing surface on each side of the cam and prevent binding. The cam type has a capacity of 1/4 to 3/4 inch.

(4) The heavy-duty, wedge-type, stud remover socket works on the wedge principle and takes a positive grip which can be released only when the tool is turned in the reverse direction. Two sizes of steel wedges are included with the socket. This type has a capacity of 9/16 to 1 inch.

f. Torque wrenches. A torque wrench (fig 15) is used for work requiring a particular force (torque) to tighten bolts, nuts, capscrews, etc, to a desired degree of pressure. A dial or scale calibrated in foot-pounds or inch-pounds indicates the degree of torque placed on the work. The pointer moves to the right or left of zero depending on the bolt (left- or right-hand threads) being tightened. These wrenches are issued in several sizes; they may have a 1/4-, 1/2-, or 3/4-inch square drive to receive socket wrenches, and capacity may vary according to need. A torque wrench enables you to set up a nut or bolt when the force applied to the handle reaches the specified limit. Manufacturer's instructions specify these limits of turning force. Cylinder head nuts and bolts, rod bearing caps, and other places on automotive and airplane engines usually require torque wrench limits.

g. Care of wrenches. Clean all wrenches after use. Apply thin film of oil to metal parts of all wrenches prior to storing. Wrenches that come in sets, such as socket wrenches, should be returned to their cases after being used. For long periods of storage, the wrenches should be covered with a rust-preventive compound and carefully stored in a dry place. The torque wrench, in particular, must be carefully placed in its box to prevent damage to the dial or scale.

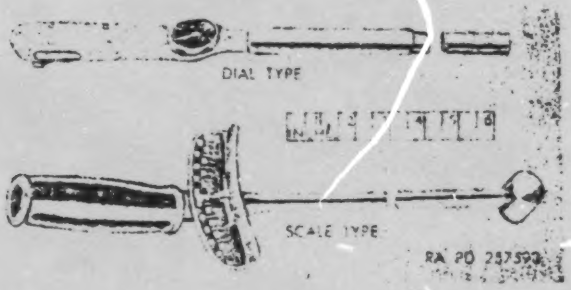


Figure 15. Torque wrenches.

h. Nonsparking wrenches. Nonsparking wrenches are wrenches that will not cause sparks to be generated when working with steel nuts and bolts. They are generally made from a copper alloy (bronze); however, they may be made from other nonsparking materials. Nonsparking wrenches must be used in areas where flammable materials are present. These tools are used extensively when working around gasoline carrying vehicles and when working around aircraft.

120

i. Rules for wrenches. There are a few basic rules that you should keep in mind when using wrenches. They are:

(1) Always use a wrench that fits the nut properly.

(2) Keep wrenches clean and free from oil. Otherwise they may slip, resulting in possible serious injury to you or damage to the work.

(3) Do not increase the leverage of a wrench by placing a pipe over the handle. Increased leverage may damage the wrench or the work.

(4) Provide some sort of kit or case for all wrenches. Return them to it at the completion of each job. This saves time and trouble and facilitates selection of tools for the next job. Most important, it eliminates the possibility of leaving them where they can cause injury or damage to men or equipment.

(5) Determine which way a nut should be turned before trying to loosen it. Most nuts are turned counterclockwise for removal. This may seem obvious, but even experienced men have been observed straining at the wrench in the tightening direction when they wanted to loosen it.

(6) Learn to select your wrenches to fit the type of work you are doing.

4. FILES. Files are used for cutting, smoothing off, or removing small amounts of metal. Files are made in various lengths, shapes, and cuts, and spacing of their teeth. Every file has five parts: the point, edges, face of cutting teeth, heel or shoulder, and tang (fig 16).

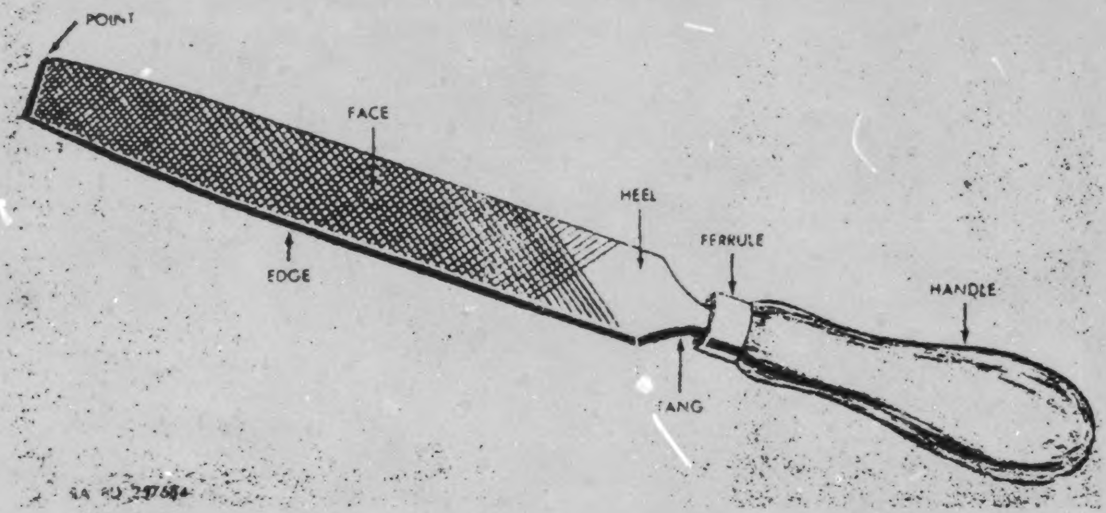


Figure 16. Parts of a file.

a. Types of files. File teeth characteristics.

(1) Single cut. Single cut files (fig 17) have a single set, diagonal row of teeth. The teeth are parallel to each other throughout the file.

(2) Double cut. Double cut files (fig 17) have two sets of diagonal rows of teeth. The first set of teeth is called the overcut. On the top of the overcut set, a second set is made crossing the first. The second set is called the upcut and is not as coarse or as deep as the overcut

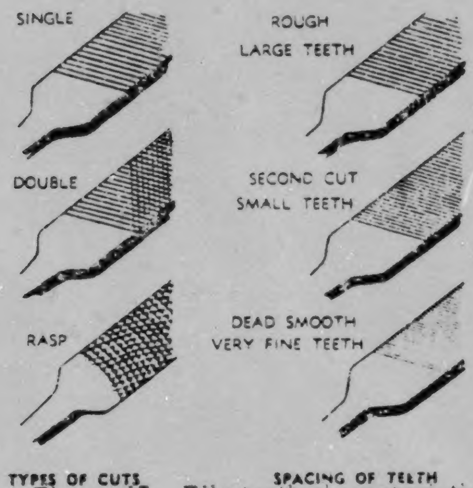


Figure 17. File teeth characteristics.

(3) Rasp cut. Rasp cut files (fig 7) are made by a single pointed tool or punch which forms each short tooth separately. Teeth are formed consecutively, side by side, to form a line or a row of teeth.

b. File teeth spacing. The number of teeth per inch spacing (fig 17) varies slightly with the make of file. The spacing also changes with the file length, increasing proportionately as the length of the file is increased. A file may have a rough, coarse, bastard (medium coarse), second cut, smooth cut, and dead smooth grade teeth. For fast removal of metal or for rough work, the rough coarse and bastard files are used. For finishing, the second cut (small teeth), smooth cut (very small teeth), and the dead smooth (very fine teeth) are used.

c. File shapes (fig 18).

(1) Flat files. A flat file is rectangular in cross section and is slightly tapered toward the point in both width and thickness and has double-cut teeth. Both edges are cut.

(2) Hand files. A hand file is similar to a flat file, but is of uniform width and tapers in thickness only. It is double cut with one safe or uncut edge.

(3) Square files. A square file tapers slightly toward the point on all four sides and is double cut.

(4) Round files. A round file tapers slightly toward the point. The bastard cut files, 6 inches and longer, are double cut. The second cut round files, 12 inches and longer, are double cut. All others are single cut.

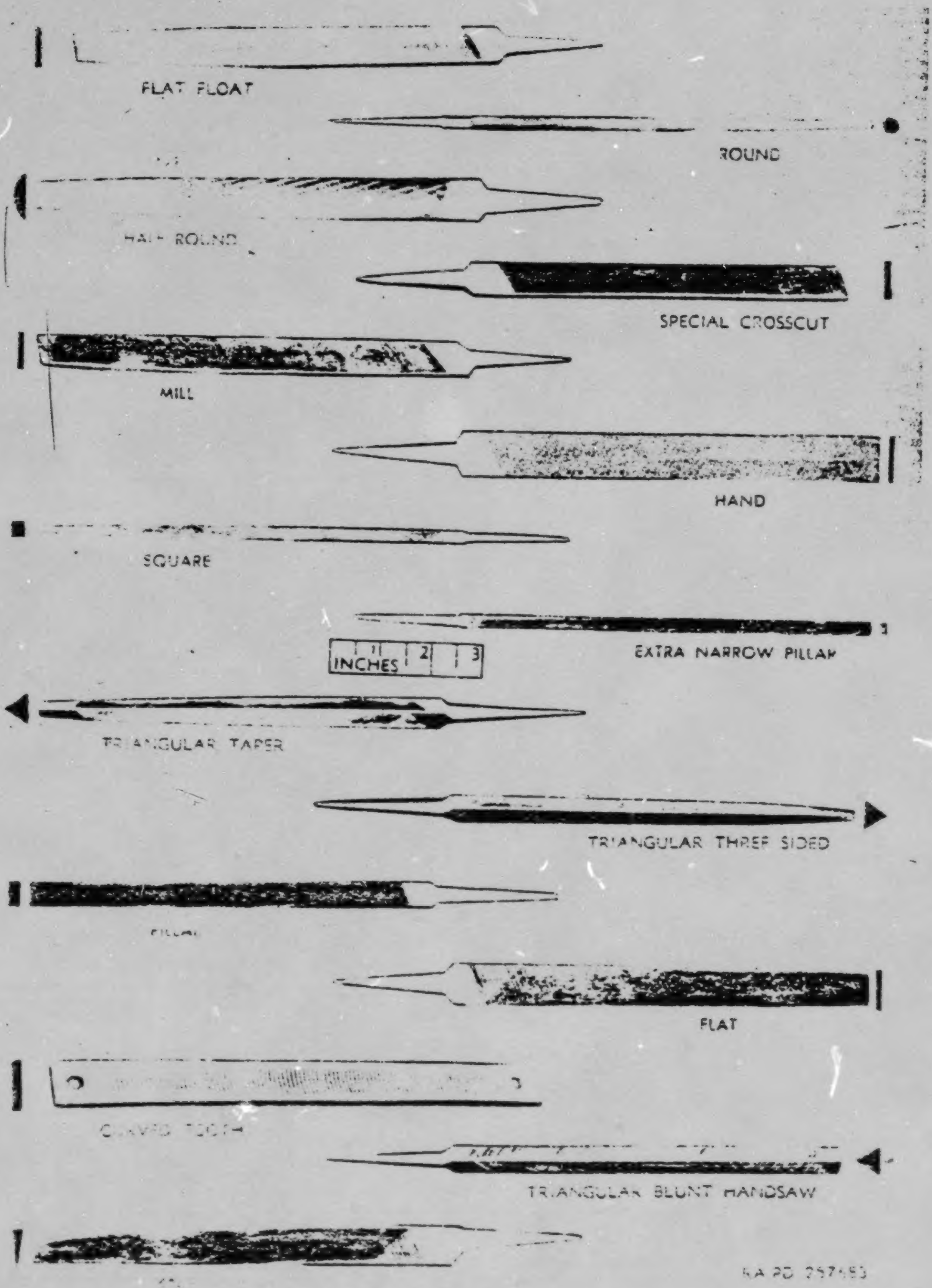

FLAT FLOAT
ROUND
HALF ROUND
SPECIAL CROSSCUT
MILL
HAND
SQUARE
EXTRA NARROW PILLAR
1
2
3
INCHES
TRIANGULAR TAPER
TRIANGULAR THREE SIDED
PILLAR
FLAT
CURVED TOOTH
TRIANGULAR BLUNT HANDSAW
RA PD 357453

Figure 18. Types of files.

(5) Half-round files. A half-round file tapers toward the point in widths and thickness. The flat sides of all half-round files are double cut and are graded in coarseness like flat files. The round backs of all coarse and bastard half-round files are double cut. The backs of files longer than 6 inches are double cut, while the backs of 4- and 6-inch files are single cut.

(6) Mill files. A mill file is usually single cut and is tapered in width and thickness for about a third of its length.

(7) Pillar files. A regular or an extra narrow pillar file is similar to a hand file only it is narrower. Pillar files are double cut with one safe or uncut edge. Pillar files are of the same coarseness as square files of corresponding lengths.

(8) Triangular files. The taper file tapers toward the point, is usually single cut, and has edges that are set and cut for filing the gullet between saw teeth. The blunt handsaw file is of uniform width and thickness and its teeth are similar to those of the taper file. The three-sided file tapers toward the point, is double cut, and has fairly sharp corners.

(9) Knife files. A knife file is shaped like a knife blade and is double cut on both faces.

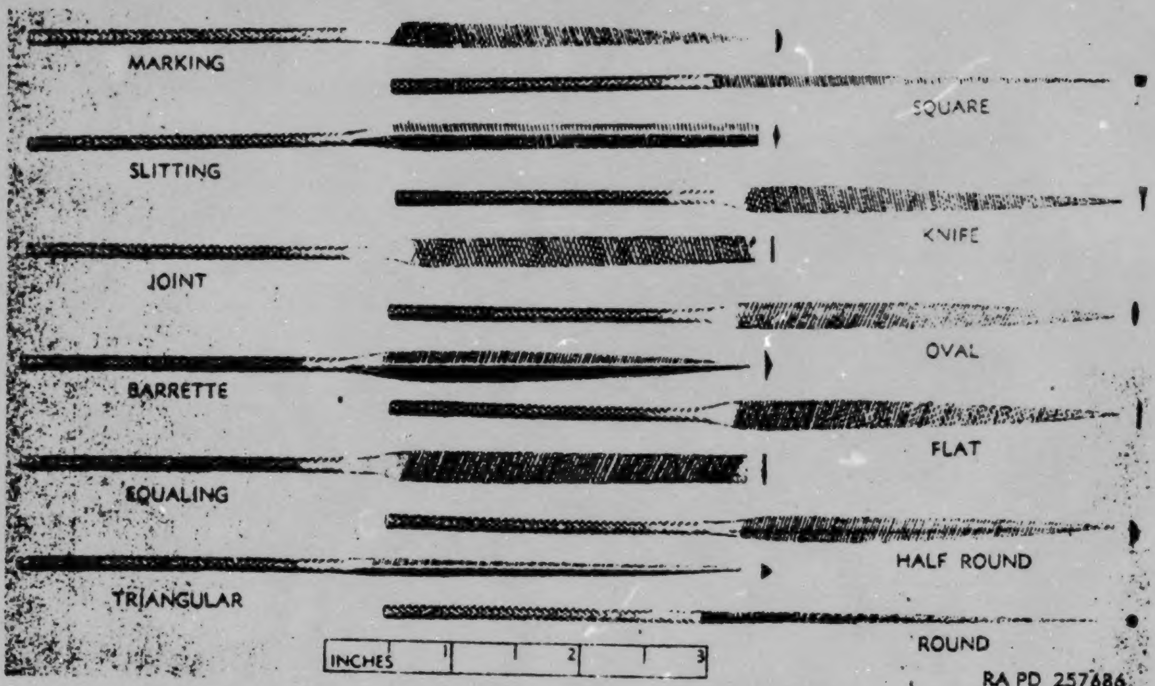
(10) Flat float files. Flat float files are slightly tapered in width and thickness and have a coarse cut.

(11) Curved tooth files. The curved tooth file has single cut, curved milled teeth, and is sometimes called a vixen or body file.

(12) Special crosscut saw files. The special crosscut saw file is single cut and of uniform width and thickness.

(13) Swiss pattern files. Swiss pattern files (fig 19) are small and delicate. The tang is shaped into a handle. They are most often used for fitting parts of delicate mechanisms, for filing work in instruments, and tool and die work. They are made in seven cuts—00, 0, 1, 2, 3, 4, and 6. They are usually supplied in sets of 8 or 12 assorted files in a box although individual files are issued. The handles are knurled for a better grip. The Swiss pattern files are designed in 12 different shapes.

d. Use of files. There are thousands of kinds, cuts, and sizes of files. This is due to the fact that there are thousands of different filing jobs, each of which can be done better by using the right file for the job. Therein lies the first rule on how to get the most out of files. The right file enables doing the job properly, whereas the wrong one does not and often, in fact, ruins the work. The right file saves time because it performs correctly, and usually faster, on the kind of metal or work for which it was designed. The right file permits a greater number of efficient filing strokes. Many factors enter into the selection of the right file for the job. In general, it may be said that different files are required to file a flat or convex surface; to file a curved or concave surface; to file an edge; to file a notch, a slot, or a square or round hole. But these factors can immediately become complicated by the kind of metal or other material to be filed; the kind, shape, and hardness of the object or part to be filed; the location, size, and character of the surface, edge, notch, slot, or hole to be filed; the amount of metal to be removed; and the degree of smoothness or accuracy required. All these conditions have a bearing on the kind, size, and cut of file which will best attain a particular objective.


MARKING
SQUARE
SLITTING
KNIFE
JOINT
OVAL
BARRETTE
FLAT
EQUALING
HALF ROUND
TRIANGULAR
ROUND
INCHES
1
2
3

RA PD 257686

Figure 19. Swiss pattern files.

e. Selecting proper file.

(1) For heavy, rough cutting, a large coarse, double cut file is best.

(2) For finishing cuts, use a second cut or smooth cut, single cut file.

(3) When working on cast iron, start with a bastard cut file and finish with a second cut file.

(4) When filing soft metal, start with a second cut.

(5) When filing hard steel, start with a smooth cut file and finish with a dead smooth file.

(6) When filing brass or bronze, start with a bastard cut file and finish with a second or smooth cut file.

(7) When filing aluminum, lead, or babbitt metal, use a bastard cut curved tooth file.

(8) For small work use a short file; for medium sized work use an 8-inch file; for large work use a file that is most convenient.

f. Method of filing.

(1) Clamp the work securely in a vise so that the area to be filed is horizontal and is parallel to, and projecting slightly above, the vise jaws.

(2) Hold the file handle in one hand, thumb on top, and hold the tip of the file with the fingers of the other hand.

(3) Apply pressure on the forward stroke only. Unless the file is lifted from the work on the return stroke, it will become dull much sooner than it should. When filing soft metals, pressure on the return stroke helps keep the cuts in the file clean of waste metal.

(4) Use a rocking motion when filing round surfaces.

(5) When using a new file, do not apply too much pressure since the teeth will break off - do not force the file. File slowly, lightly, and steadily. Too much speed and too much pressure causes the file to rock and will round off the corners of the work.

(6) Draw filing is used to produce a very smooth and true surface. To draw file, hold the file at right angles to the direction of the strokes, with your hands close together to prevent bending or breaking the file. Pressure should not be great and can remain the same on the back stroke, as well as on the draw stroke. The speed of filing is not important. For extra-smooth surfaces, wrap a piece of emery cloth around the file and stroke in the same manner.

g. Care and safety precautions.

(1) Breaking in. A new file should be broken in by using it first on brass or bronze. Never use it first to remove the fins or scales on cast iron. Do not use a new file on a narrow surface, such as sheet metal, because the narrow edge of the metal is likely to break off the sharp points on the file teeth.

(2) Cleaning. After using a new file, the teeth will clog up with metal filings. Using a clogged file will scratch the work - this condition is called pinning. One way to help prevent pinning is by rubbing chalk between the teeth before filing. However, the best method to keep the file clean is to use a file scorer and file cleaner brush. A scorer is a small pointed metal instrument, often furnished with the file cleaner brush, and is used for cleaning out individual teeth and grooves in the file clogged too tightly with metal to clean with the brush. When cleaning a file with a file scorer, use a pulling motion, holding the file scorer blade parallel to the rows of teeth. Finish cleaning by brushing the file parallel to the rows of teeth with the file cleaner brush.

(3) Safety precautions.

(a) Do not throw files in a drawer or tool box where they can rub against each other or against other tools. Store them in separate holders, such as clips, straps, or in holes cut in a block of wood.

(b) Use the files as instructed and clean them often.

(c) Never use a file without a securely attached handle unless it is of the Swiss pattern type.

(d) Do not use files for a purpose other than for which they were intended.

(e) Do not use oil since this will cause the file to slide across the work preventing fast cutting.

(f) Never strike the file against a vise or other object to remove filings. Use the file cleaner brush.

(g) Never store files with lubricants or rust-preventive compounds on them. Wrap each file in a waterproofed barrier wrapping paper and place the files in racks or boxes so that the faces or edges of the files will not touch each other. Keep files dry.

5. HACKSAWS. Hacksaws are saws used for cutting metal, much the same as a carpenter's saw cuts wood. Common hand hacksaws have either adjustable frames or solid frames. Hacksaw blades of various types are inserted in these frames, for different kinds of work. Adjustable frames can be changed to hold blades from 8 to 16 inches long; solid frames, although more rigid, will take only the length blade for which they are made. This length is the distance between the two pins which hold the blade in place. All hacksaw frames hold the blades either parallel or at right angles to them and are provided with screws for pulling the blades tight.

a. Hacksaw blades. Hacksaw blades are made of high-grade tool steel, hardened and tempered. There are two types: all-hard and flexible. All-hard blades are hardened throughout, while only the teeth of the flexible blades are hardened. All blades are from 7/16 to 9/16 inch wide, have from 14 to 32 teeth per inch, and are from 8 to 18 inches long. Each blade has a hole at each end which hooks to pins in the frame.

b. Set. The teeth of all hacksaw blades are set to provide clearance for the blade; the three different kinds of set are alternate set, raker set, and undulated set. Alternate set means that alternate teeth are bent slightly sidewise in opposite directions; on a raker set blade, every third tooth remains straight and the other two are set alternately; on an undulated set blade, short sections of teeth are bent in opposite directions. A blade should be set just enough to give a free, smooth, rapid cut in a slot just wider than the blade itself, removing no more stock than is necessary.

c. Selecting hacksaw blades. Selecting the best hacksaw blade for a specific job is a question of using either an all-hard or flexible blade having a pitch (number of teeth per inch) best suited to the work in hand.

(1) An all-hard blade is best for sawing brass, tool steel, cast iron, rails, and other stock of heavy cross section.

(2) In general, a flexible blade is best for sawing hollow shapes and metals of light cross section, such as channel iron, tubing, tin, copper, aluminum, or babbitt.

(3) Use a blade with 14 teeth per inch on machine steel. This coarse pitch makes the saw free and fast cutting.

(4) Use a blade with 18 teeth per inch on solid stock, aluminum, babbitt, tool steel, high speed steel, cast iron, and so on. This pitch is recommended for general use.

(5) Use a blade with 24 teeth per inch on tubing, tin, brass, copper, channel iron, and sheet metal over 18 gage. If a coarser pitch is used, the thin stock will tend to strip the teeth out of the blade and make it difficult to push the saw. Two or more teeth should be in contact with the work.

(6) Use a blade with 32 teeth per inch on thin-walled tubing and conduit and sheet metal thinner than 18 gage.

6. DRILLS.

a. General. The making of a hole is piece of material can, in some instances, be a simple operation, but in a service section it is an important and precise job. A large number of different tools and machines have been designed so that holes may be made speedily, economically, and accurately in all kinds of material. In order to be able to use these tools efficiently, it is well to become acquainted with them. The most common tool for making holes is the drill. It consists of a cylindrical piece of steel with spiral grooves. One end of the cylinder is pointed; the other end is shaped so that it may be attached to a portable or stationary drilling machine. The grooves, usually called flutes, may be cut into the steel cylinder, or the flutes may be formed by twisting a flat piece of steel into cylindrical shape. Drills of this kind are sometimes referred to as twist drills. Twist drills are made either of carbon steel or high-speed steel; the nature of carbon steel is such that if it is heated excessively and allowed to cool, it will lose its hardness; high-speed steel, on the other hand, has the property of "red hardness"; that is, it can become red hot without losing its temper. For any drilling at high speed, therefore, high-speed twist drills should be selected to obtain best results and lasting cutting effectiveness. The three principal parts of twist drills are the body, shank, and point (fig 20), and they are available with either two, three, or four flutes. Drills having three or four flutes are used for following smaller drills or for enlarging cored holes and are not suitable for drilling into solid stock. The spiral flutes give twist drills four definite advantages:

(1) A correct rake to the lips.

(2) Cause chips formed while drilling to curl tightly so that they occupy the minimum amount of space.

(3) Form channels through which such chips can escape from the hole.

(4) Allow the lubricant, when oil is used, to flow easily down to the cutting edge of the drill.

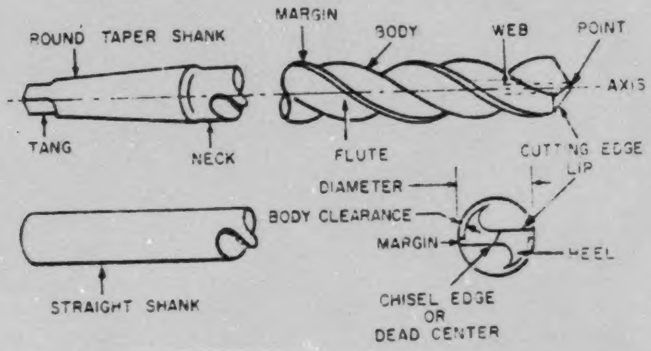


Figure 20. Twist drill nomenclature.

b. Types and uses.

(1) Two fluted. Standard for cutting holes in solid metal.

(2) Three or four fluted. Used for enlarging holes.

c. Drill sizes.

(1) Fractional - 1/64 to 3 inches by 64ths.

(2) Numbered - 1 to 80 - 80 smallest (0.0135) and 1 largest (0.228).

(3) Lettered - A to Z - A smallest (0.234) and Z largest (0.412).

d. Care of drills.

(1) Never attempt to enlarge a hole by tipping drill sideways. This will cause breakage.

(2) Do not allow drills to overheat while in use or while being sharpened.

(3) Seat drills with lead hammer.

(4) Do not place work supporting blocks far from drill - springiness will cause it to snap.

(5) A great deal of damage can be done to a drill through careless handling. Large drills, in particular, because of their weight, can be scarred and chipped quite easily. For this reason, it is recommended that they be handled with care and that a procedure be set up which will minimize such dangers. The use of partitioned trays or wooden stands or blocks with holes for drills will help to lengthen the effective life of drills.

e. Lubricants. When drilling, some materials require no lubricant while others require a lubricant peculiar to their nature. The following may be used as a guide:

(1) Tool steel - oil.

(2) Soft steel - oil or soda water.

(3) Wrought iron - oil or soda water.

(4) Cast iron - dry.

(5) Brass - dry.

(6) Copper - oil.

(7) Babbitt - dry.

(8) Glass - turpentine.

7. SHEARS AND CUTTERS.

a. Hand shears.

(1) One of the handiest tools for cutting light sheet metal is the hand snip (thin snips). The straight hand snips (fig 21) have blades that are straight and cutting edges that are sharpened to an 85° angle. Snips like this can be obtained in different sizes ranging from the small 6-inch snip to the large 14-inch. They are designed to cut sheet metal up to one-sixteenth inch in thickness. They will also work on slightly heavier gages of soft metals such as aluminum alloys.

(2) Snips will not remove any metal when a cut is made. There is danger, though, of causing minute metal fractures along the edges of the metal during the shearing process. For this reason it is better not to cut exactly on the layout line in an attempt to avoid too much finish work.

(3) Cutting extremely heavy gage metal always presents an opportunity to spring the blades. Once the blades are sprung, hand snips are useless. Use the rear portion of the blades only when cutting heavy material. This not only avoids the possibility of springing the blades but also gives you greater cutting leverage.

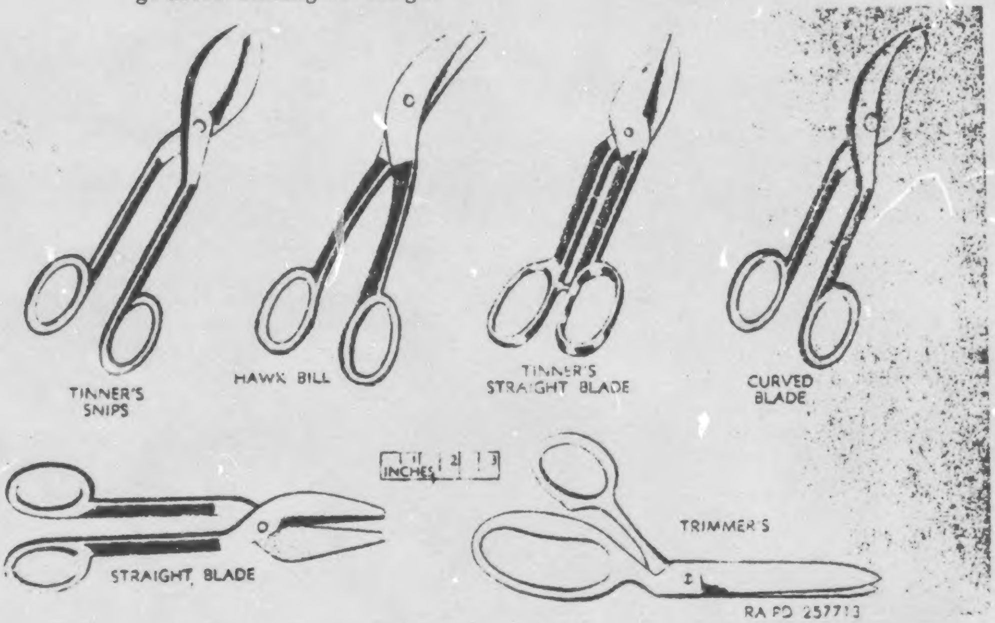


Figure 21. Hand shears.

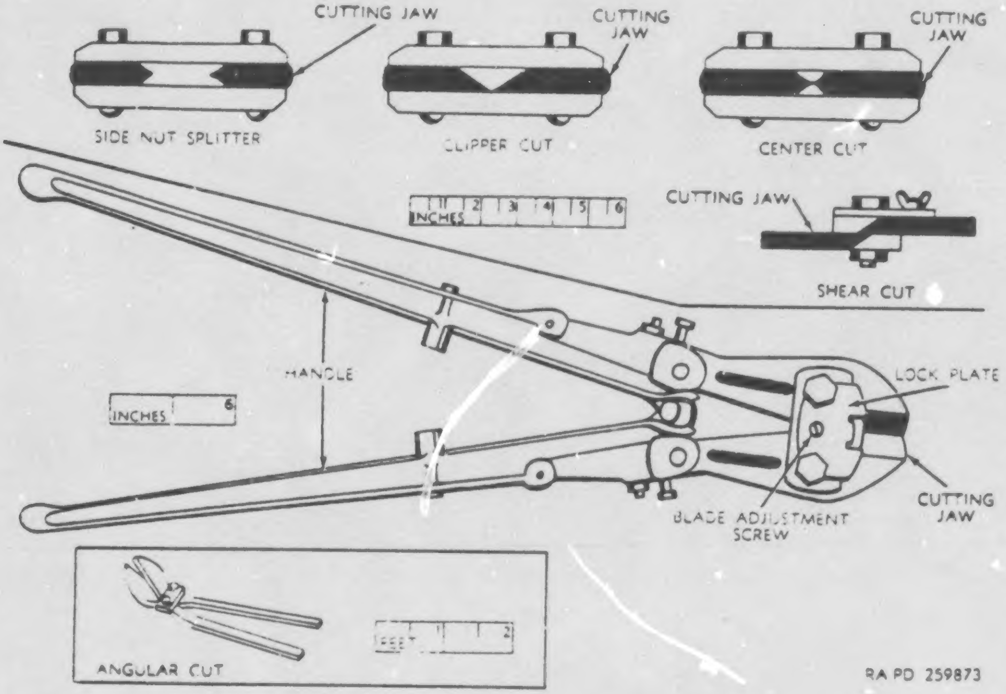
(4) It is hard to cut circles or small arcs with straight snips. There are snips expecially designed for circular cutting. They are called hawk-bill snips and aviation snips. Use these snips in the same manner as you would use straight snips and observe the same precautions. Like straight snips they come in many different sizes.

(5) Many snips have small serrations (notches) on the cutting edges of the blades. This tends to prevent them from slipping backwards when a cut is being made. Although this feature does make the actual cutting much easier, it mars the edges of the metal slightly. You can remove these small cutting marks if you allow proper clearance for dressing the metal to size. There are many other types of hand snips used for special jobs. The snips discussed here can be used for almost any common type of work.

(6) Learn to use snips properly. They should always be oiled and adjusted to permit ease of cutting and to produce a surface that is free from burs. If the blades bind, or if they are too far apart, the snips should be adjusted.

(7) Never use snips as screwdrivers, hammers, or pry bars. They break easily. Do not attempt to cut heavier materials than the snips are designed for. Never toss snips in a toolbox where the cutting edges can come into contact with other tools. This dulls the cutting edges and may even break the blades. When snips are not in use, hang them on hooks or lay them on an uncrowded shelf or bench. Never use tin snips to cut hardened steel wire or other similar objects. Such use will dent or nick the cutting edges of the blades.

b. Bolt cutters. Bolt cutters (fig 22) are used to cut bolts, rods, wire rope, cable, screws, rivets, nuts, bars, strips, and wire. A bolt cutter is shaped like a giant shears with short blades and long handles. Different cutting edges are designed for specific applications.


CUTTING JAW
SIDE NUT SPLITTER
CUTTING JAW
CLIPPER CUT
CUTTING JAW
CENTER CUT
INCHES 1 2 3 4 5 6
CUTTING JAW
SHEAR CUT
HANDLE
INCHES 6
LOCK PLATE
BLADE ADJUSTMENT SCREW
CUTTING JAW
ANGULAR CUT
FEET 1 2

RA PD 259873

Figure 22. Types of bolt and nut cutters.

c. Care of shears and cutters. Keep tools clean at all times. Lubricate pivot screw or bolt with a drop of light oil. Remove rust with a fine aluminum oxide abrasive cloth. Apply a thin film of oil on tools to prevent rust, and hang tools on hooks or place them on a shelf when not in use. Never throw tools in a box where the cutting edges may be damaged. Do not attempt to cut material harder than the tool was designed to handle. Never use shears or cutters as a hammer or a pry bar, since they are easily damaged. For long periods of storage, coat tools with a rust preventive compound and store them in a dry place where the cutting edges do not come in contact with other metal objects.

8. CHISELS.

a. Chisels are tools that can be used for chipping or cutting metal. They are made from a good grade tool steel with a hardened cutting edge and a beveled head. They will cut any metal that is softer than materials of which they are made. When it is skillfully used, the chisel can be made to do most any job that a milling machine can do, although it is perhaps less accurate and requires greater time and energy.

b. Usually the bar stock from which a chisel is forged is octagonal (eight-sided). Cold chisels are classified according to the shape of their points, and the width of the cutting edge denotes their size. The most common shapes of chisels are flat (cold chisel), cape, roundnose, and diamond point (fig 23 thru 26).

Figure 23. Machinist's flat (or cold) chisel.

Figure 24. Diamond point chisel.

Figure 25. Cape chisel.

Figure 26. Roundnose chisel.

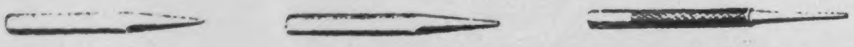
c. The type chisel most commonly used is the flat cold chisel which serves to cut rivets, split nuts, chip castings, and cut thin metal sheets. Also used for special jobs is the cape chisel for cutting keyways, narrow grooves, and square corners; the roundnose chisel for semicircular grooves and for chipping inside corners with a fillet; and the diamond point for cutting V-grooves and sharp corners.

d. As with other tools there is a correct technique for using a chisel. Select a chisel that is large enough for the job. Be sure to use a hammer that matches the chisel; that is, the larger the chisel the heavier the hammer. A heavy chisel will absorb the blows of a light hammer and will do virtually no cutting. As a general rule, hold the chisel in the left hand with the thumb and first finger about 1 inch from the top. It should be held steadily but not tightly. The finger muscles should be relaxed, so if the hammer strikes the hand it will slide down the tool and lessen the effect of the blow. Keep the eyes on the cutting edge of the chisel, not on the head, and swing the hammer in the same plane as the body of the chisel. If you have a lot of chiseling to do, slide a piece of rubber hose over the chisel. This will lessen the shock to your hand.

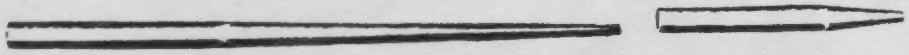
e. When using a chisel for chipping, always wear goggles to protect your eyes. If other men are working close by, see that they are protected from flying chips by erecting a screen or shield to contain the chips. Remember that the time to take these precautions is before you start the job.

9. PUNCHES.

a. A hand punch is a tool that is held in the hand and struck on one end with a hammer. There are many kinds of punches designed to do a variety of jobs and most are made of tool steel. The part held in the hand is usually octagonal shaped or it may be knurled. This prevents the tool from slipping around in the hand. The other end is shaped to do a particular job. Figure 27 shows some of the most commonly used metal punches.



Prick punch. Center punch. Drive pin punch.



Alining punch. Drift.

Figure 27. Commonly used metal punches.

b. Drift punches, sometimes called "starting punches," have a long taper from the tip to the body. They are made that way to withstand the shock of heavy blows. They may be used for knocking out rivets after the heads have been chiseled off, or for freeing pins which are "frozen" in their holes. After a pin has been loosened or partially driven out, the drift punch may be too large to finish the job. The followup tool to use is the pin punch, for it is designed to follow through the hole without jamming. Always use the largest drift or pin punch that will fit the hole. These punches usually come in sets of three to five assorted sizes and will have flat points, never edged or rounded. To remove a bolt or pin that is extremely tight, start with a drift punch that has a point diameter slightly smaller than the diameter of the object you are removing. As soon as it loosens, finish driving it out with a pin punch. Never use a pin punch for starting a pin, because it has a slim shank and a hard blow may cause it to bend or break.

c. Another punch you will use a lot is the center punch. As the name implies, it is used for marking the center of a hole to be drilled. If you try to drill a hole without first punching the center, the drill will "wander" or "walk away" from the desired center. Another use of the center punch is to make corresponding marks on two pieces of an assembly to permit reassembly in the original positions. The point of a center punch is accurately ground central with the shank, usually at a 60° angle, and is difficult to regrind by hand with any degree of accuracy. It is, therefore, advisable to take care of a center punch and not to use it on extremely hard materials.

d. Other punches have been designed for special uses. One of these is the soft-faced drift. It is made of brass or fiber and is used for such jobs as removing shafts, bearings, and wrist pins from engines. It generally heavy enough to resist damage to itself, but soft enough not to injure the finished surface on the part that is being driven.

e. A prick punch is made of hardened tool steel ground to a slender, long tapered, cone-shaped point terminating in a sharp 30° conical tip. It is used to mark or identify scribed or layout lines on a piece of work, usually soft metal such as brass. These marks are made at short intervals so that the reference lines will be easily located.

10. **PLIERS.** Pliers are used for gripping, cutting, bending, forming, or holding work, and for special jobs. Tongs look like long-handled pliers and are mainly used for holding or handling hot pieces of metal work to be forged or quenched, or hot pieces of glass. Pliers basically consist of a pair of jaws designed for a specific purpose, a pivot or hinge, and a pair of handles. They are made in many shapes and sizes to handle a variety of jobs. The size is determined by the overall length, which usually is 5 to 10 inches.

a. Types of pliers

(1) Slip joint combination pliers. The slip joint combination pliers (fig 28) are most commonly used to hold or bend wires, small bars, and a wide variety of miscellaneous items. Some have short cutting edges near the hinge for cutting wire. The slip joint permits adjustment and wider opening of the jaws. The jaws have serrations or teeth for gripping.

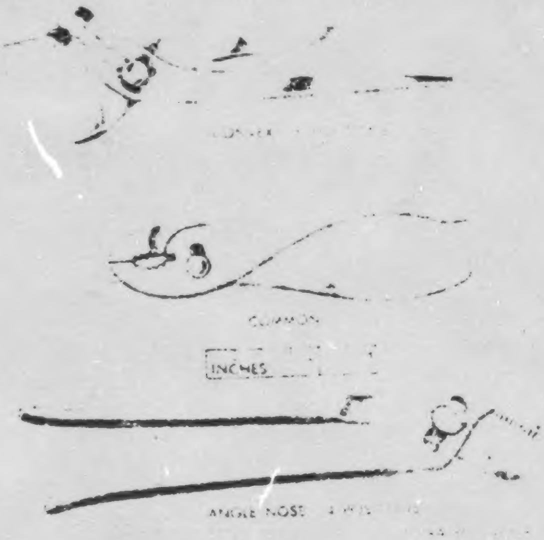


Figure 28. Slip joint combination pliers.

(2) Diagonal cutting pliers. Diagonal cutting pliers (fig 29) have short jaws with the cutting edges at a slight angle. They are used for cutting soft wire and stock and for removing cotter pins. They are also used for cutting cotter pins to desired length and for spreading the ends after the pin is inserted through a hole.

(3) Lineman's side cutting pliers. Lineman's side cutting pliers (fig 29) are for cutting wire and peeling insulation. The flat serrated jaws are also used to twist wire ends together in making splices.

(4) Parallel jaws, flat, and roundnose pliers. These pliers (fig 30) are used to bend or form metal into various shapes and to work in limited spaces. The nose is made in variety of widths and lengths. The parallel jaws pliers are supplied with or without side cutters.

(5) Special purpose pliers. Some pliers are made for specific jobs such as the brake spring pliers, glass holding and breaking pliers, ignition pliers, battery terminal pliers, and brake key and snapring pliers.

b. Use of pliers. When using pliers keep your fingers away from the jaws and cutting edges. Make sure the hinge or joint is tight before using pliers. Insulate handles of pliers when using them in electrical work with several thicknesses of friction tape, rubber tape, or specially manufactured rubber grips. When cutting large material within the capacity of diagonal cutting pliers, cut with the throat of the jaws, not with the points. The tendency of misalining the jaws will be greatly reduced. Once the jaws are misalined (sprung), it will be impossible to cut fine wire. To preserve the life of slip joint combination pliers, do not use them on very hard metal. Hard metal will wear off the teeth and the pliers will lose their grip. Use pliers only for the purpose for which they are intended. Do not try to increase the leverage of their handles by lengthening them with sections of pipe or other extensions.

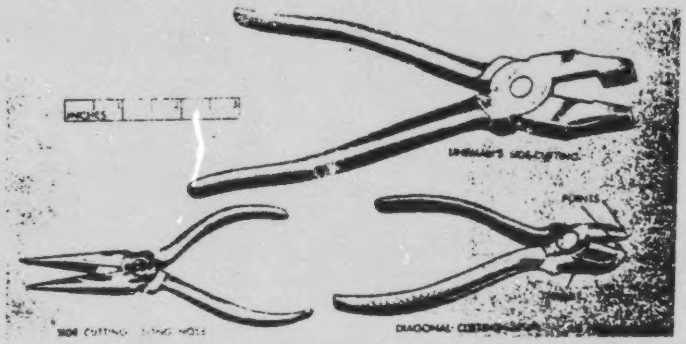


Figure 2 . Diagonal and side cutting pliers.

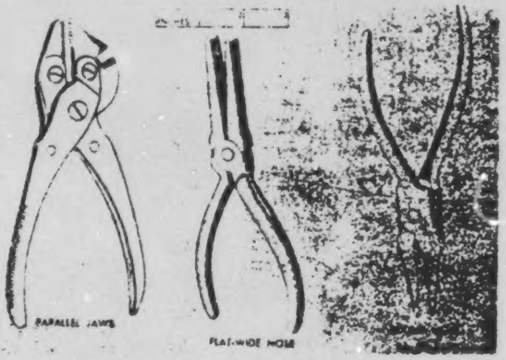


Figure 30. Parallel jaws, flat and roundnose pliers.

11. SCREWDRIVERS. Screwdrivers are used for driving or removing screws or bolts with slotted or special heads.

a. Types of screwdrivers. Screwdrivers are made in various shapes and lengths to perform specific jobs. The size of a screwdriver (fig 31) is indicated by the length of the blade; i. e. ; a 6-inch screwdriver has a 6-inch blade. The width and shape of blade tips vary from a narrow parallel sided tip to a wide tapered tip. Some screwdrivers have special tips for cross-slotted recessed screws or bolts and clutch-bit screws. Special screwdrivers are provided with a ratchet arrangement.

(1) Common screwdriver. The common screwdriver (fig 32) has a round steel blade anchored in a wood or plastic handle. The blade is forged from alloy steel and tempered. The tip is flat, not forged to size, and heat treated. Common screwdrivers are tapered to give maximum strength. Handles are made of hardwood or plastic composition, usually fluted for a good grip. The blade is anchored in the handle by two or more tongs on the end of the blade, and in the case of a wood handle by a pin or rivet through the ferrule, handle, and blade. Some handles are integral; that is, the blade forms an integral part of some of the outside surface of the handle and is locked in place by rivets. Integral blade screwdrivers are used for heavy-duty work. The blade can be tapped with a hammer to seat the blade tip in rusty screws. Other common heavy-duty screwdrivers have square blades so that a wrench can be used to turn them.

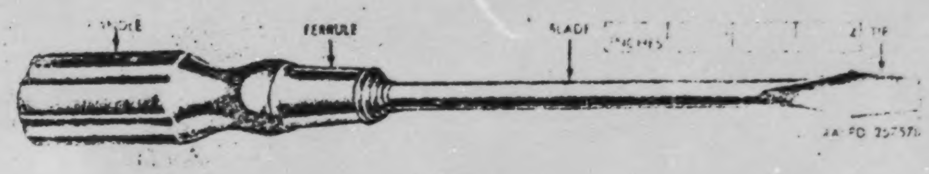

HANDLE
FERRULE
BLADE
INCHES
TIP
RA PD 257576

Figure 31. Standard screwdriver.

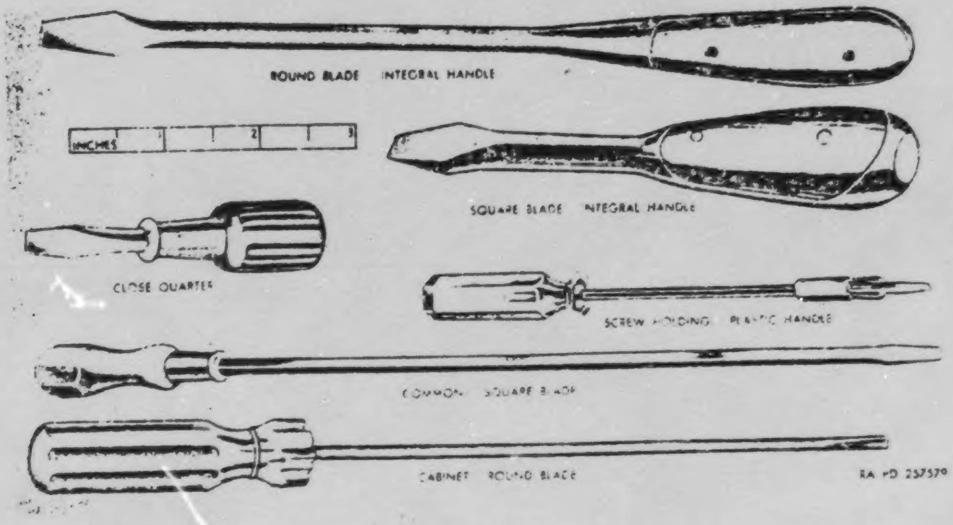

ROUND BLADE INTEGRAL HANDLE
INCHES
1
2
3
SQUARE BLADE INTEGRAL HANDLE
CLOSE QUARTER
SCREW HOLDING PLASTIC HANDLE
COMMON SQUARE BLADE
CABINET ROUND BLADE
RA PD 257579

Figure 32. Common, flat-tip screwdrivers.

(2) Phillips screwdrivers (cross-tip). The tip of a Phillips screwdriver (fig 33) is shaped like a cross so that it fits into Phillips-head screws. Phillips-head screws have two slots which cross at the center. These screwdrivers are made with four different sized tips. Size 1 will fit No 4 and smaller size Phillips screws; size 2 will fit No 5 to 9 inclusive; size 3 will fit No 10 to 16 inclusive; and size 4 will fit No 18 and larger sizes. Phillips screwdrivers also have different length blades ranging from 1 inch to 8 inches.

(3) Reed and Prince screwdrivers (cross-point). Reed and Prince screwdrivers are similar to the Phillips type; however, do not confuse them for the tip is different, as shown in figure 33. These screwdrivers are issued in 3- to 8-inch sizes.

(4) Clutch-head screwdrivers. Clutch-head screwdrivers (fig 33) are used to drive clutch-bit screws. These screws are commonly called butterfly or figure 8 screws and have recessed heads. The clutch-type screwdriver is issued in 3-, 4-, 5- and 6-inch sizes.

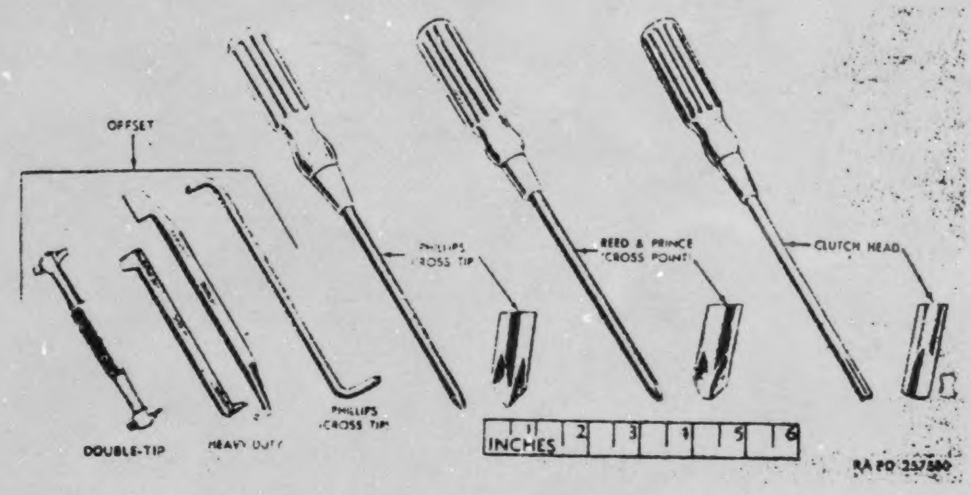


Figure 33. Special tipped screwdrivers.

(5) Offset screwdrivers. Offset screwdrivers (fig 33) are designed to drive or remove screws that cannot be lined up with the axis of common screwdrivers or are located in tight corners. An offset screwdriver is usually made from a piece of steel, round or octagonal in shape, machined so that the end portion is at right angles to its longitudinal axis. They are made in a variety of sizes having different width tips. Some offset screwdrivers are made with two blades, one of different size at each end. A double-tip offset screwdriver has four blades.

(6) Ratchet screwdrivers. Ratchet screwdrivers (fig 34) are used to drive or remove small screws rapidly. The spiral ratchet screwdriver automatically drives or removes screws. It can be adjusted to turn left, right, or locked to act as a common screwdriver. It has a knurled sleeve with a spiral chuck and a control locking device which has three positions: right and

left ratchet and rigid. Some spiral ratchets have a spring in the handle which automatically returns the handle for the next stroke. Another style of ratchet screwdriver has a knurled collar for rotating the blade with your fingers. The spiral type has separate blades that are inserted in the chuck. The plain common ratchet screwdriver is made with one integrally built blade.

(7) Screwdriver bits. A screwdriver bit (fig 34) is a screwdriver blade with a square, hex, or notched shank so that it will fit in the chuck of a breast drill or ratchet bit brace, or on a square drive tool such as a socket wrench handle. Other screwdriver bits are made with a spiral ratchet screwdriver shank for use with spiral ratchets.

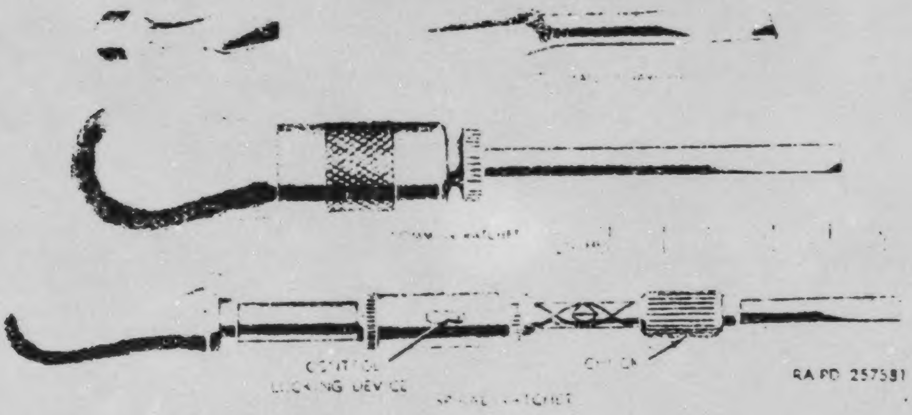
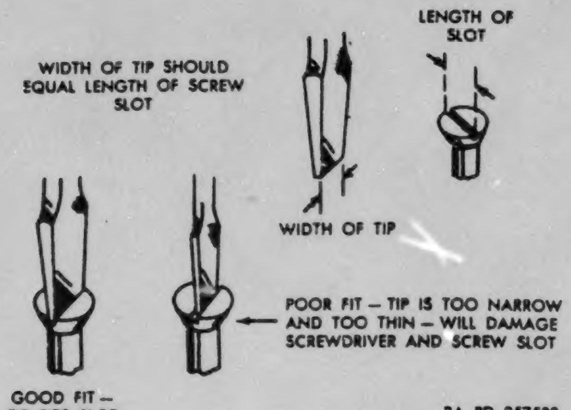


Figure 34. Ratchet screwdrivers and screwdriver bits.

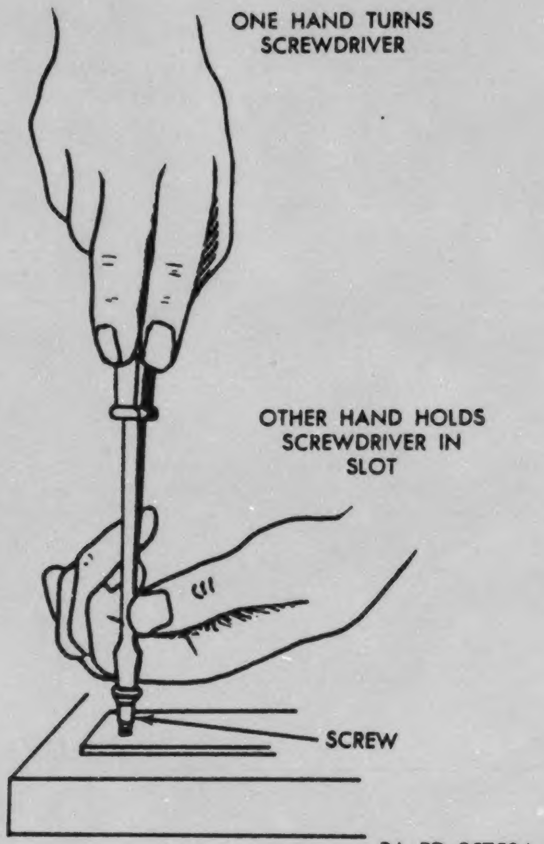
b. Using a screwdriver.

(1) Driving screws. Use the longest screwdriver available which is convenient for the work. The width of the tip should equal the length of the screw slot and the tip must be thick enough to fit the width of the screw slot (fig 35). Hold the handle firmly in one hand with the head of the handle against the palm and grasp the handle near the ferrule with your thumb and finger (fig 36). Hold the screwdriver in line with the axis of the screw and center the tip in the screw slot. To drive screw in, press down with your palm and turn the screwdriver clockwise (to the right). When taking a fresh grip on the handle, steady the tip and keep it pressed in the screw slot with your other hand. Relax your other hand when you are ready to turn the screwdriver again. To drive screws easier, rub a little soap into the threads of a wood screw and put a drop of oil or a little graphite on a machine screw. Doing this will also minimize the chances of rust forming on the screws and will make them easier to remove.


WIDTH OF TIP SHOULD EQUAL LENGTH OF SCREW SLOT
LENGTH OF SLOT
WIDTH OF TIP
POOR FIT – TIP IS TOO NARROW AND TOO THIN – WILL DAMAGE SCREWDRIVER AND SCREW SLOT
GOOD FIT – TIP FITS SLOT

RA PD 257583

Figure 35. Proper blade for specific screw.


ONE HAND TURNS SCREWDRIVER
OTHER HAND HOLDS SCREWDRIVER IN SLOT
SCREW

RA PD 257584

Figure 36. Holding screwdriver properly.

(2) Removing tight screws. When a screw cannot be turned at the first attempt to remove it, try to tighten it first, then turn the screwdriver opposite. Sequentially, tighten and loosen the screw until completely removed. If a tight screw with a damaged slot can be backed out partially, it is possible to remove it completely with a pair of pliers.

c. Care of screwdrivers.

(1) Dressing and shaping. When a screwdriver becomes nicked, or the edges become rounded, or when other damage occurs so that it does not fit a screw slot, it must be reground or filed. The sides must be parallel to keep the tool from lifting from the screw slot, and the tip must be square and at right angles to the sides and to the blade. If using a file, place the screwdriver in a vise. When using a grinder, adjust the rest to hold the screwdriver against the wheel to produce the desired shape, parallel or concave. Do not grind away more material than necessary to remove nicks or square up the end. After squaring the tip, grind both sides until the tip is the required thickness. Dip the screwdriver into water frequently during grinding to prevent loss of temper by overheating. If the blade discolors (blue or yellow), the temper has been damaged. Retemper by heating about 1-1/2 inches of blade to a cherry red with a torch. Immediately dip about 3/4 inch of the blade in clean cold water. Quickly rub the hardened end with aluminum oxide abrasive to brighten it. Watch the color creep back into the tip from the heated portion of the blade. When the color becomes light blue, dip the blade into water. The tip is now retempered and ready for use.

(2) Precautions. Handle the screwdriver carefully. Use the right sized screwdriver for the job. Keep the blade clean. Do not carry a screwdriver in your pocket unless it has a pocket clip. Never use a screwdriver for prying or chiseling operations. When difficulty is encountered in driving or removing screws that are hard to turn, do not use pliers to turn the screwdriver. Pliers will damage the screwdriver. For hard to turn screws, select a square bladed screwdriver designed for heavy duty, and a wrench which properly fits the blade.

(3) Storage. After use, wipe the screwdriver with light oil and place in a rack or toolbox.

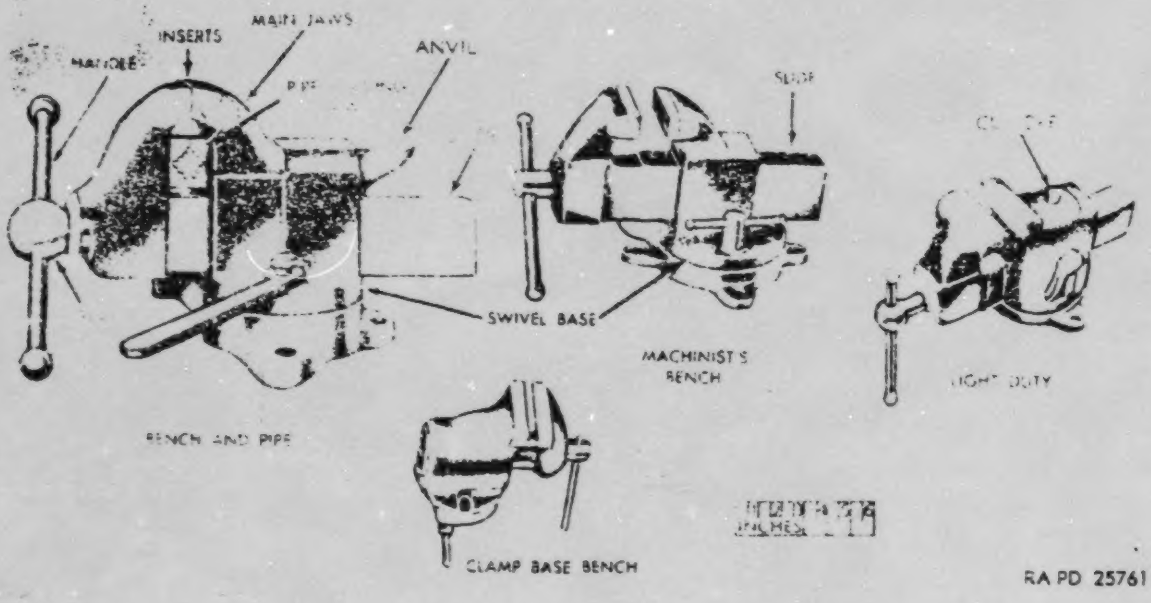
12. VISES. Vises are used for holding work when it is being planed, sawed, drilled, shaped, sharpened, riveted, or when wood is being glued.

a. Types of vises.

(1) Machinist's bench vise. A machinist's bench vise (fig 37) is a large steel vise with rough jaws that prevent the work from slipping. Most of these vises have a swivel base with jaws that can be rotated, while others cannot be rotated. A similar light-duty model is equipped with a cutoff. These vises are usually bolt-mounted onto a bench.

(2) Bench and pipe vise. The bench and pipe vise (fig 37) has integral pipe jaws for holding pipe from 3/4 inch to 3 inches in diameter. The maximum working main jaw opening is usually 5 inches, having a jaw width of 4 to 5 inches. The base can be swiveled to any position and locked. These vises are equipped with an anvil and are also bolted onto a workbench.

(3) Clamp base bench vises. The clamp base bench vise (fig 37) usually has a smaller holding capacity than the machinist's or bench and pipe vises and is clamped to the edge of a bench. Holding capacity is generally 1-1/2 to 3 inches. These vises normally do not have pipe holding jaws.



RA PD 257611

Figure 37. Types of vises.

(4) Blacksmith's vise. The blacksmith's vise (fig 38) is used for holding work that must be pounded with a heavy hammer. It is fastened to a sturdy workbench or wall, and the long leg is secured into a solid base on the floor.

(5) Pipe vises. A pipe vise (fig 38) is specifically designed to hold round stock. The vise shown has a capacity of 1 to 3 inches. One jaw is hinged so that the work can be positioned and then the jaw brought down and locked. This vise is also used on a bench. Some pipe vises are designed to use a section of chain to hold down the work. Chain pipe vises range in size from 1/8 to 2-1/2-inch pipe capacity up to 1/2 to 8-inch pipe capacity.

(6) Machine table vise. The machine table vise (fig 39) is constructed so that it may be secured on a machine table and work held for subsequent machining operations. These vises either have a 3-1/2-inch jaw width and a 3-inch jaw opening, or a 6-inch jaw width with a 6-inch jaw opening.

(7) Pin vise. A pin vise (fig 39) is held in the hand. Its overall length is usually about 4 inches. It has a chuck-type jaw which is capable of holding small stock from 0 to 0. 187 inch in diameter.

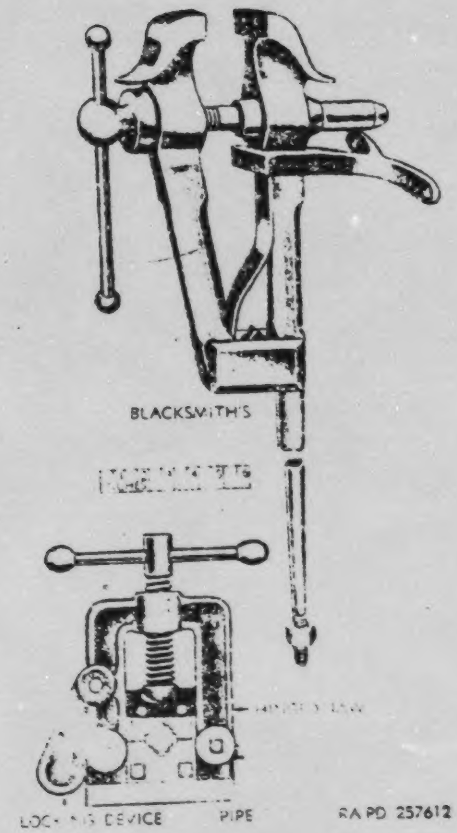

BLACKSMITH'S
HINGED JAW
LOCKING DEVICE
PIPE
RA PD 257612

Figure 38. Blacksmith's and pipe vises.

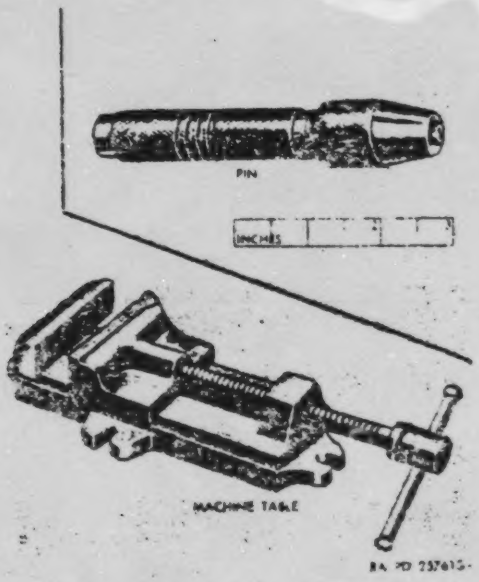

PIN
INCHES
MACHINE TABLE
RA PD 257615

Figure 39. Special purpose vises.

b. Use of vises.

(1) When holding soft metal in a vise, material softer than the workpiece must be used in the jaws to prevent damage to the work. The work should be held securely to prevent it from slipping, but not so tight that it will damage the work.

(2) When holding hard material, turn the screw of the vise up tight and tap the end of the handle sharply for the final tightening.

(3) To hold irregularly shaped work in a vise requires a little thought. Make certain the jaws grip on a firm even surface of the work. The swivel jaw type of vise (not illustrated) is especially suited to hold tapered or irregular work, since one jaw can be swiveled. A tapered pin must be removed before the jaw can be swiveled.

(4) Cylindrical work can be held between straight jaws; however, it is better to insert V-cut jaws over the straight jaws for this work.

(5) Finished work should be held between jaws of soft material or soft metal, such as copper, brass, lead, or plastic. A piece of rawhide or soft leather laid over the vise jaws will prevent damage to highly polished surfaces.

c. Care of vises. Keep vises clean at all times; they should be cleaned and wiped with light oil after using. Never strike a vise with a heavy object and never hold large work in a small vise, since this practice will cause the jaws to become sprung or otherwise damage the vise. Keep jaws in good condition and oil the screws and the slide frequently. Never oil the swivel base or swivel jaw joint—its holding power will be impaired. When the vise is not in use, bring the jaws lightly together or leave a very small gap and leave the handle in a vertical position.

13. CLAMPS. Clamps are used for holding work that cannot be satisfactorily held in a vise, because of its shape or size, or when a vise is not available. Clamps are generally used for light work.

a. Types of clamps.

(1) C-clamps. A C-clamp (fig 40) is shaped like the letter C. It consists of a steel frame threaded to receive an operating screw with a swivel head. They are made for light, medium, and heavy service in a variety of sizes.

(2) Hand screw clamps. A hand screw clamp (fig 40) consists of two hard maple jaws connected with two operating screws. Each jaw has two metal inserts into which the screws are threaded. These clamps are also issued in a variety of sizes.

(3) Toolmaker's clamps. One type of toolmaker's clamp (fig 40) is similar to the hand screw clamp, except that the jaws are made of forged steel. The screws pass through one jaw and thread into the opposite jaw. One jaw is kept from sliding down the screw by means of a clip which slips under the knurled head of the screw. The other screw, farthest from the clamp opening, is threaded through one jaw and enters a shallow bearing hole in the other. These clamps are issued in 1-1/4-, 2-1/2-, and 3-1/2-inch capacities. Another type of toolmaker's clamp has one adjustable jaw and uses takeup blocks. The takeup blocks are slipped on and off the end of the adjustable jaw. The clamp can be attached to a bench so that it can be used as a small vise.

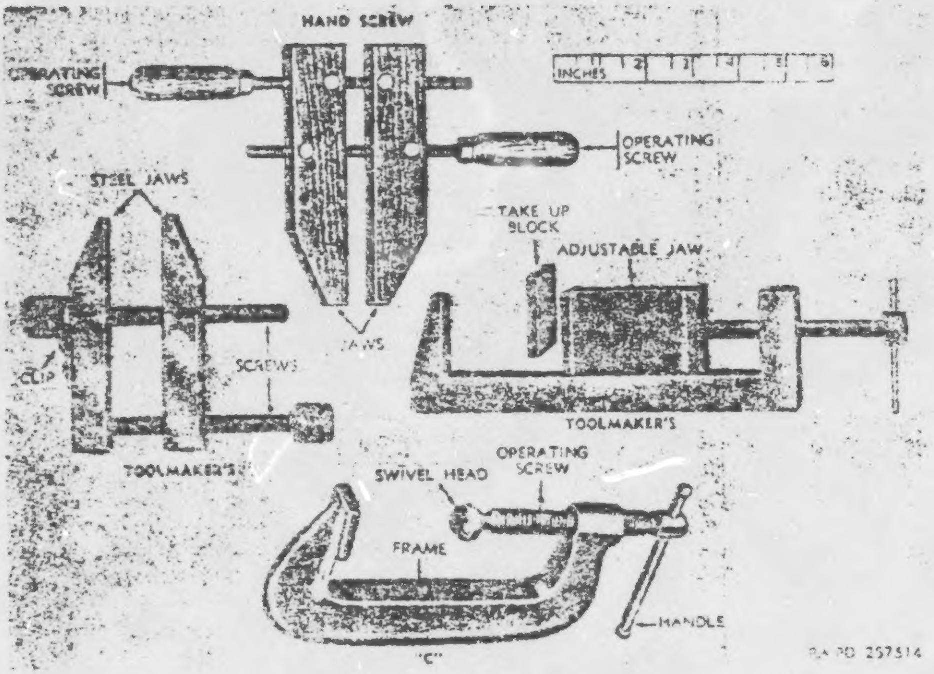

HAND SCREW
OPERATING SCREW
INCHES 1 2 3 4 5 6
OPERATING SCREW
STEEL JAWS
TAKE UP BLOCK
ADJUSTABLE JAW
JAWS
CLIP
SCREWS
TOOLMAKER'S
TOOLMAKER'S
SWIVEL HEAD
OPERATING SCREW
FRAME
HANDLE
"C"
RA PD 297514

Figure 40. Types of clamps.

b. Use of clamps.

(1) When using the hand screw clamp, keep the jaws parallel to apply even pressure along the work and to properly hold the pieces of work together (fig 41).

(2) When soft material can be damaged by the jaws, a soft material should be placed over the face of each jaw.

(3) Use rawhide or soft leather to protect highly polished surfaces.

(4) Never use the hand screw clamp on material other than wood. Other materials may damage the wooden jaws.

(5) A C-clamp may be used on any kind of material. When holding glass or work with a high polish or paint finish, protect the finish by using brass shims or wooden blocks on each side of the work.

(6) Clamps should be screwed up tight, but not so tight that the pressure will spring the clamp.

(7) Use hand pressure to tighten clamps; never use wrenches or bars (fig 42).

(8) Always use the right size clamp and observe clamps for signs of undue strain when using them.

(9) When using the toolmaker's steel jaw clamp, both screws are turned to adjust the clamp roughly, then the screw nearest the open end of the clamp is adjusted until the clamp fits the work snugly. Then, tighten the clamp by turning the other screw. The jaws should be parallel and should clamp the work evenly. If one screw leads or lags the other, the clamp is useless; it will allow the work to turn. Back off one screw and tighten the other to correct an uneven clamping condition. The knurled heads of these screws are drilled for insertion of a short, steel rod which can be used to increase leverage.

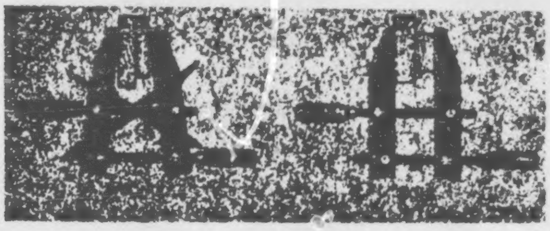


Figure 41. Using hand screw clamps—jaws parallel.

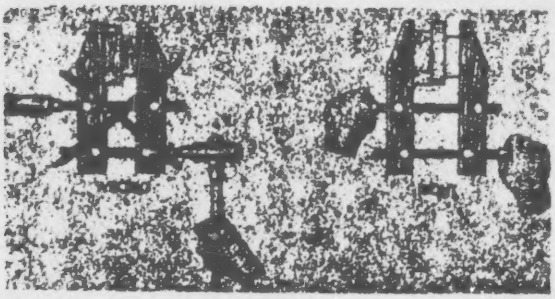


Figure 42. Using hand screw clamps—hand tightened.

c. Care of clamps.

(1) C-clamps. Keep threads of C-clamps clean and free from rust by oiling properly. The swivel head must be kept clean, smooth, and grit free. If the swivel head becomes damaged, replace it as follows: pry open the crimped portion of the head and remove the head from the ball end of the screw (fig 43). Replace with a new head and crimp. Oil screw threads regularly (fig 44). For short storage, oil clamps with a light coat of engine oil and wipe them off before they are hung on racks or pins, or are carefully placed in a tool box. For long storage, apply a rust-preventive compound to the C-clamp.

JAW
RA PD 257617

Figure 43. C-clamp, exploded view.

(2) Hand screw clamps. The screws of these clamps may break or become damaged, the inserts may become worn, or the wooden jaws may split or warp. When necessary to replace any of these parts, disassemble the clamp (fig 45). Remove handles from screws by filing off peened ends of attaching pins. Drive out the pins. Turn both screws from the inserts and remove the inserts from the jaws. Replace damaged screws, inserts, and handles. Install inserts in the jaws and turn the screws into position in the two jaws. Turn the new screw into the handle or the old screw into the new handle, depending on which part is being replaced. Aline holes and tap in a new pin. Peen end of pin to secure the screw in the handle. Keep all screws lubricated with a few drops of light oil. Apply a light coat of linseed oil to wood surfaces to prevent them from drying out. If the finish of wooden jaws is worn and bare wood is exposed, coat the jaws with varnish (fig 44). Hang the clamps on racks or pins, or carefully place them in a toolbox, to prevent damage when not in use. Wipe clean before storing.

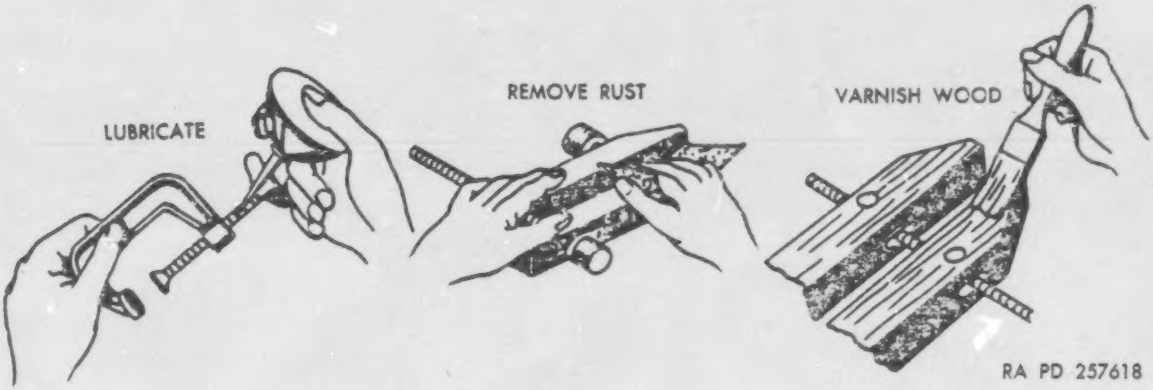


Figure 44. Clamp maintenance.

(3) Toolmaker's clamps. Keep the screw threads clean and oiled for smooth operation. Protect the jaws from rust with a thin coating of light oil. Remove rust with crocus or aluminum oxide cloth (fig 44). If the jaws become chipped or marred, dress them with an oilstone to provide a smooth contacting surface.

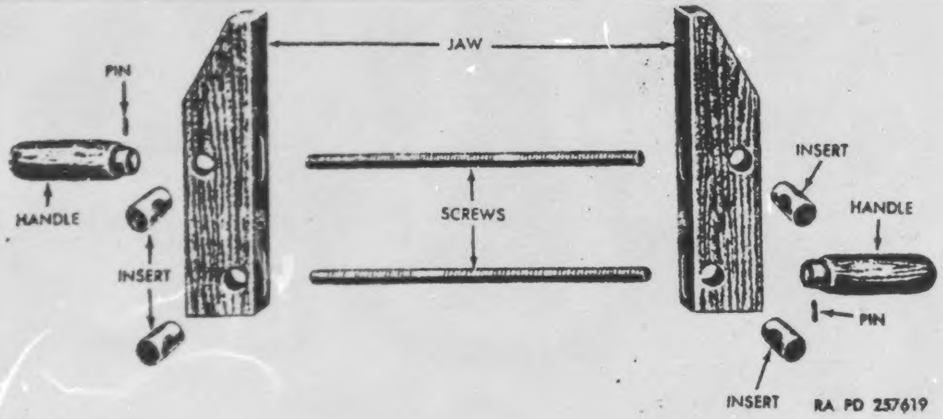


Figure 45. Hand screw clamp, exploded view.

14. TAPS AND DIES. Taps and dies are used to cut threads in metal, plastics, or hard rubber. The taps are used for cutting internal threads, and the dies are used to cut external threads. There are many different types of taps; however, the most common are the taper, plug, bottoming, and pipe taps (fig 46).

a. Types of taps.

(1) The taper (starting) hand tap has a chamfer length of 8 to 10 threads. These taps are used when starting a tapping operation and when tapping through holes.

(2) Plug hand taps have a chamfer length of 3 to 5 threads and are designed for use after the taper tap.

(3) Bottoming hand taps are used for threading the bottom of a blind hole. They have a very short chamfer length of only 1 to 1-1/2 threads for this purpose. This tap is used after the plug tap has already been used. Both the taper and plug taps should precede the use of the bottoming hand tap.

(4) Pipe taps are used for pipe fittings and other places where extremely tight fits are necessary. The tap diameter, from end to end of the threaded portion, increases at the rate of 3/4 inch per foot. All the threads on this tap do the cutting, as compared to the straight taps where only the non-chamfered portion does the cutting.

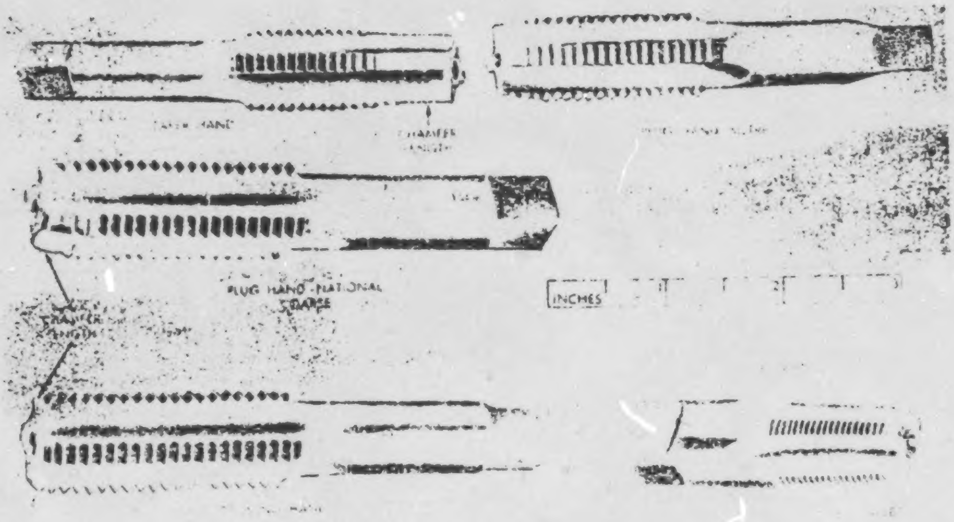


Figure 46. Types of common taps.

b. Types of dies. Dies are made in several different shapes and are of the solid or adjustable type. The square pipe die (fig 47) will cut American standard pipe thread only. It comes in a variety of sizes for cutting threads on pipe with diameters of 1/8 inch to 3 inches.

(1) A rethreading die (fig 47) is used principally for dressing over bruised or rusty threads on screws or bolts. It is available in a variety of sizes for rethreading American standard coarse and fine threads. These dies are usually hexagon in shape and can be turned with a socket, box, open end, or any wrench that will fit. Rethreading dies are available in sets of 6, 10, 14, and 28 assorted sizes in a case.

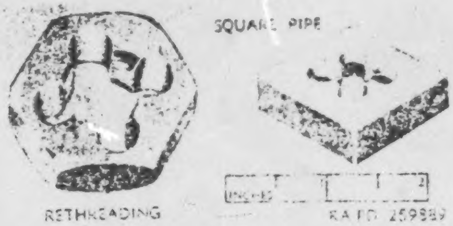


Figure 47. Types of solid dies.

(2) Round split adjustable dies (fig 48) are called "Button" dies and can be used in either hand diestocks or machine holders. The adjustment in the screw adjusting type is made by a fine-pitch screw which forces the sides of the die apart or allows them to spring together. The adjustment in the open adjusting types is made by means of three screws in the holder, one for expanding and two for compressing the dies. Round split adjustable dies

are available in a variety of sizes to cut American standard coarse and fine threads, special form threads, and the standard sizes of threads that are used in Britain and other European countries. For hand threading, these dies are held in diestocks (fig 49). One type die stock has three pointed screws that will hold round dies of any construction, although it is made specifically for open adjusting-type dies.

(3) Two-piece collet dies (fig 48) are used with a collet cap (fig 49) and collet guide. The die halves are placed in the cap slot and are held in place by the guide which screws into the underside of the cap. The die is adjusted by means of setscrews at both ends of the internal slot. This type of adjustable die is issued in various sizes to cover the cutting range of American standard coarse and fine and special form threads. Diestocks to hold the dies come in three different sizes.

(4) Two-piece rectangular pipe dies (fig 48) are available to cut American standard pipe threads. They are held in ordinary or ratchet-type diestocks (fig 50). The jaws of the dies are adjusted by means of setscrews. An adjustable guide serves to keep the pipe in alinement with respect to the dies. The smooth jaws of the guide are adjusted by means of a cam plate; a thumbscrew locks the jaws firmly in the desired position.

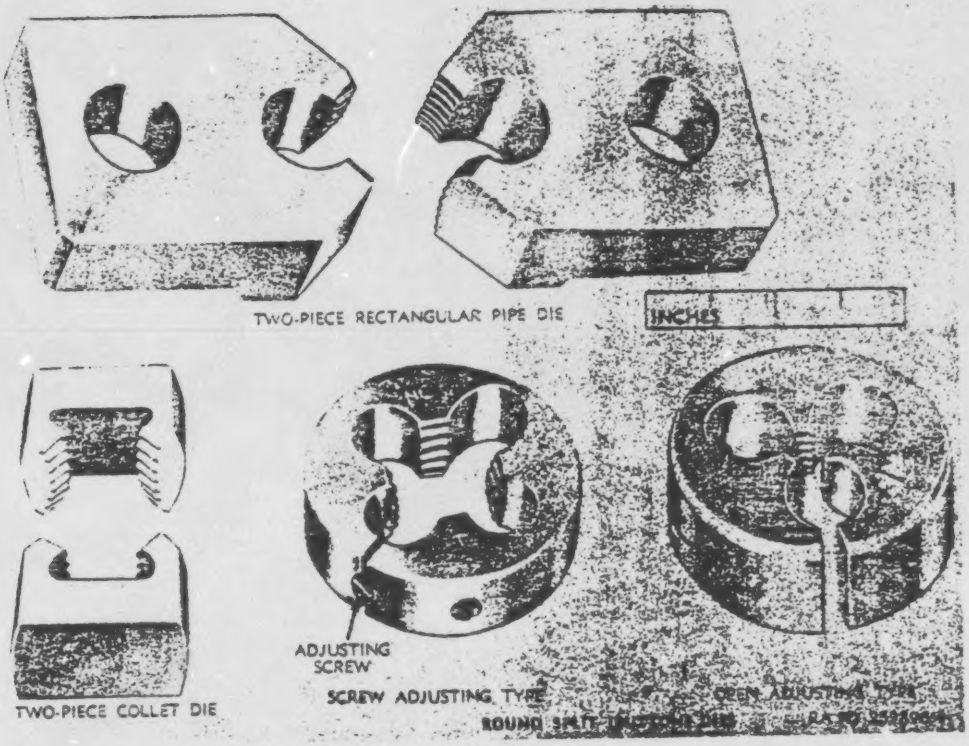


Figure 48. Types of adjustable dies.

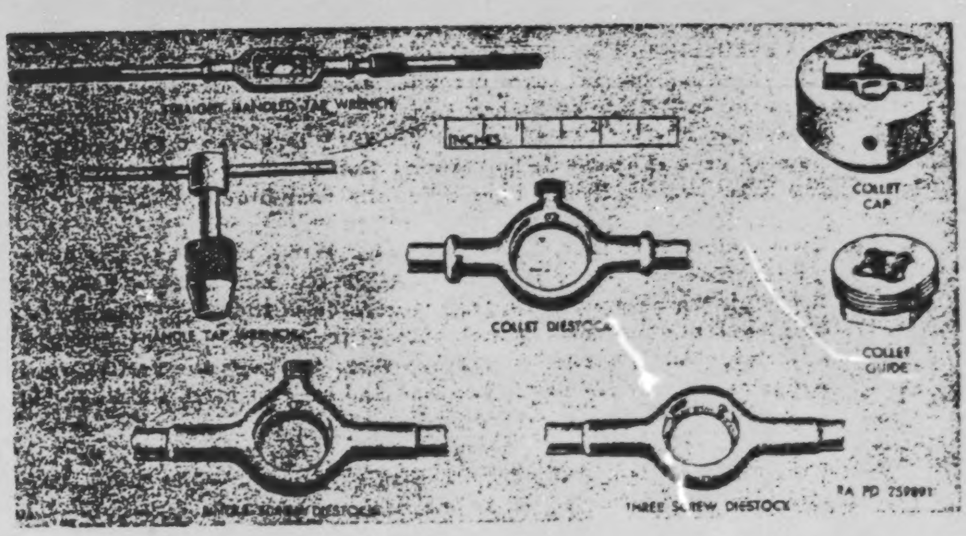

STRAIGHT HANDLED TAP WRENCH
INCHES
COLLET CAP
COLLET DIESTOCK
COLLET GUIDE
T-HANDLE TAP WRENCH
SINGLE SCREW DIESTOCK
THREE SCREW DIESTOCK
RA PD 259891

Figure 49. Diestocks, die collet and tap wrenches.

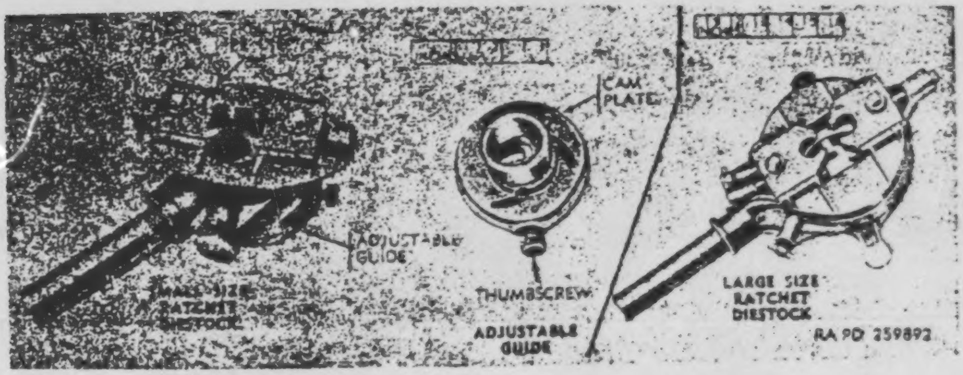
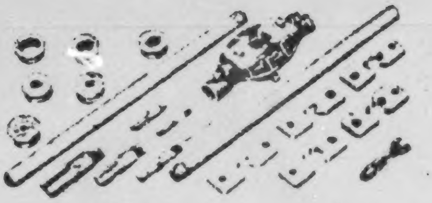

CAM PLATE
ADJUSTABLE GUIDE
SMALL SIZE RATCHET DIESTOCK
THUMBSCREW
ADJUSTABLE GUIDE
LARGE SIZE RATCHET DIESTOCK
RA PD 259892

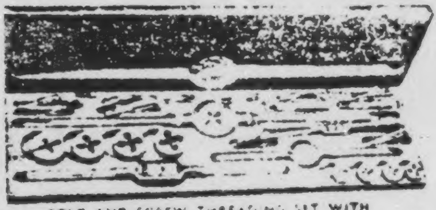
Figure 50. Adjustable die guide and ratchet diestocks.

c. Threading sets. These are available in many different combinations of taps and dies, together with diestocks, tap wrenches, guides, and necessary screwdrivers and wrenches to loosen and tighten adjusting screws and bolts. Figure 51 illustrates a typical threading set for pipe, bolts, and screws,

d. Sharpening. Never attempt to sharpen taps or dies. Sharpening of taps and dies involves several highly precise cutting processes which involve the thread characteristics and chamfer. These sharpening procedures must be done by experienced personnel in order to maintain the accuracy and the cutting effectiveness of taps and dies.



PIPE THREADING SET WITH RECTANGULAR
ADJUSTABLE DIES, DIESTOCK,
WRENCH, GUIDES AND TAPS



BOLT AND SCREW THREADING SET WITH
ROUND ADJUSTABLE SPLIT DIES,
DIESTOCKS, TAPS, TAP WRENCHES
AND SCREWDRIVERS

Figure 51. Threading sets.

e. Storing. Keep taps and dies clean and well oiled when not in use. Store them so that they do not contact each other or other tools. For long periods of storage, coat taps and dies with a rust-preventive compound, place in individual or standard threading set boxes, and store in a dry place.

15. PIPE CUTTERS. Pipe cutters are used to cut pipe made of steel, brass, copper, wrought iron, and lead.

a. Types of pipe cutters. Two pipe cutters are normally issued: one has a cutting capacity of 1/8 to 2 inches and the other from 2 to 4 inches. The pipe cutter (fig 52) has a special alloy-steel cutting wheel and two pressure rollers which are adjusted and tightened by turning the handle.

b. Use of pipe cutters.

(1) Measuring threaded pipe. Before you cut pipe, make certain the required correct length is determined. There are three methods of measuring threaded pipe, and you must understand these methods if the pipe is to be cut to the correct lengths (fig 53).

(a) End-to-end method. This measurement includes the threaded portions of the pipe. The pipe is measured from end to end.

(b) End-to-center method. This measurement is used on a section of the pipe that has a fitting screwed on one end only. Measure from the free end of the pipe to the center of the fitting at the other end of the pipe.

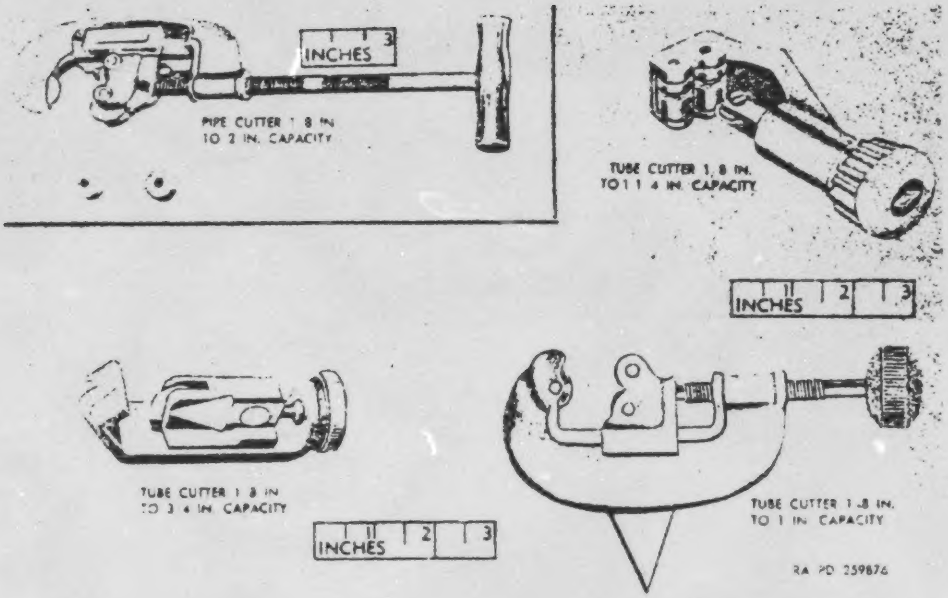

INCHES
PIPE CUTTER 1/8 IN TO 2 IN. CAPACITY
TUBE CUTTER 1/8 IN. TO 1 1/4 IN. CAPACITY
INCHES
TUBE CUTTER 1/8 IN TO 3/4 IN. CAPACITY
INCHES
TUBE CUTTER 1/8 IN. TO 1 IN. CAPACITY
RA PD 259876

Figure 52. Pipe and tube cutters.

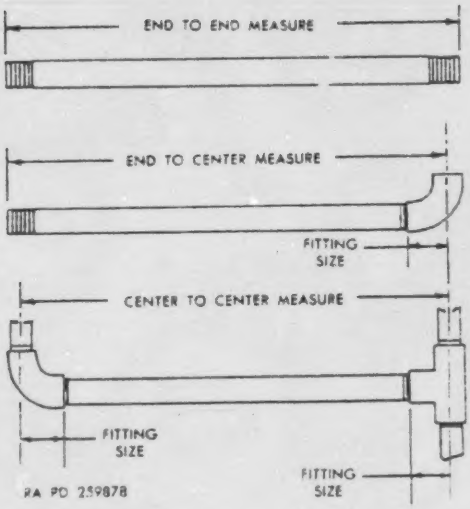

END TO END MEASURE
END TO CENTER MEASURE
FITTING SIZE
CENTER TO CENTER MEASURE
FITTING SIZE
FITTING SIZE
RA PD 259878

Figure 53. Measuring threaded pipe.

(c) Center-to-center method. This measurement is used when both ends of a pipe have fittings. Measure from the center of one fitting to the center of the other fitting at the opposite end of the pipe.

(d) Approximate thread lengths. The approximate length of thread on 1/2- and 3/4-inch wrought iron or steel pipe is 3/4 inch. On 1-, 1-1/4-, and 1-1/2-inch pipe, it is approximately 1 inch long. On 2- and 2-1/2-inch pipe, the length of thread is 1-1/8 and 1-1/2 inches respectively.

(e) Determine pipe length. To determine the length of pipe required, compute as outlined in 1 through 4, below.

1. Take the measurement of the installation, such as center to center of the pipe, requiring two fittings ((c) above).

2. Measure the size of fitting or fittings as shown in figure 53.

3. Subtract the total size of the two fittings from the measurement obtained in 1, above.

4. Multiply the approximate thread length ((d) above) by 2 and add the result to the length obtained in 3, above. This will give the length of the pipe required.

(2) Cutting pipe.

(a) Measure the length of pipe necessary ((1) above) and mark the spot where the cut is to be made with a scriber or crayon.

(b) Lock the pipe securely in a pipe vise (fig 54).

(c) Inspect the pipe cutter to make sure that there are no nicks or burs in the cutting wheel. Open the jaws of the cutter by turning the handle counterclockwise.

(d) Position the cutter around the pipe at the marked point. Make sure the cutting wheel is exactly on the mark and close the jaws of the cutter lightly against the pipe by turning the cutter handle clockwise.

(e) After making contact, turn the cutter handle clockwise one-fourth of a turn more. This will put a bit on the pipe.

(f) Grasp the cutter handle and rotate the cutter as a whole, one complete revolution, swinging it around the pipe in the direction indicated in figure 54.

(g) Turn the cutter handle clockwise one-fourth of a turn more to take another bite on the pipe and rotate the cutter, as a whole, another complete revolution. Keep the cutter perpendicular to the pipe at all times or the wheel will not track properly.

(h) Repeat (g) above until the pipe is cut. Remove the shoulder on the outside of the pipe with a file and the bur on the inside with a reamer.

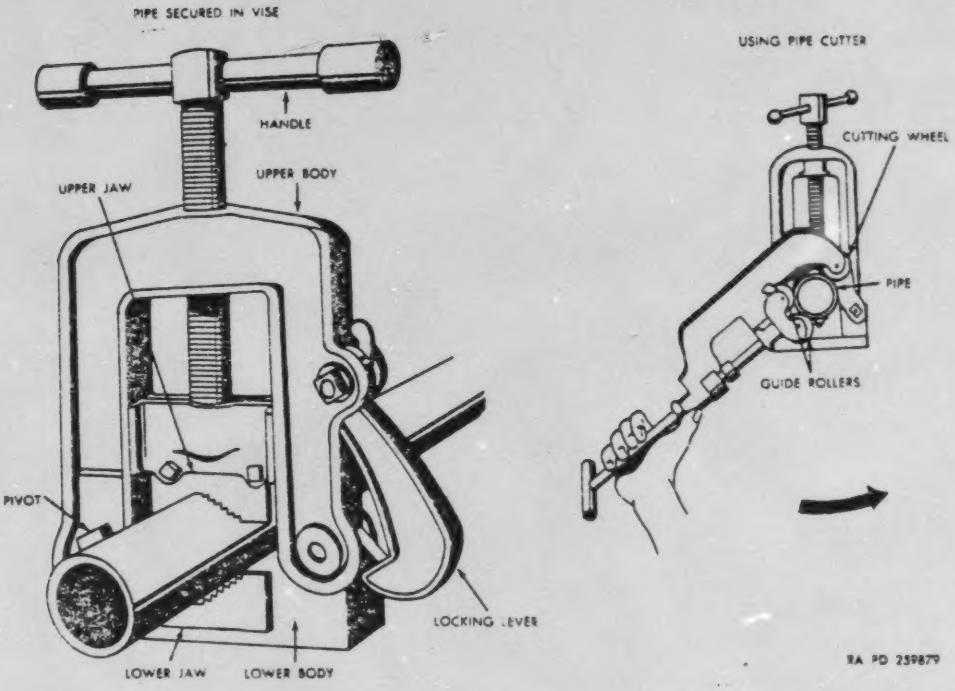

PIPE SECURED IN VISE
HANDLE
UPPER BODY
UPPER JAW
PIVOT
LOCKING LEVER
LOWER JAW
LOWER BODY
USING PIPE CUTTER
CUTTING WHEEL
PIPE
GUIDE ROLLERS
RA PD 259879

Figure 54. Cutting pipe.

c. Care of pipe cutters.

(1) Sharpening cutter wheels. The cutting wheel on a pipe cutter must be removed and sharpened when it becomes dulled, nicked, or otherwise damaged. Remove the wheel by tapping out the pin in the center of the wheel, or by backing out the attaching screw on some types. Secure the wheel in a suitable jig and carefully grind the cutting edge on a grinder abrasive wheel or grindstone. Preserve the temper by frequently dipping the cutter wheel in water during grinding. Any wire edge can be removed on an oilstone.

(2) Storage. Clean and wipe cutters with a thin film of oil before putting away after use. Carefully store tools to prevent the cutting wheels from becoming damaged. For long periods of storage, coat all parts of cutters with a rust-preventive compound; wrap cutter wheels in cotton or a small piece of rag saturated with light machine oil to prevent damage and store in a dry place.

16. TUBE CUTTERS. These cutters are used to cut tubes made of iron, steel, brass, copper, and aluminum.

a. Types of tube cutters. Some types of tube cutters closely resemble pipe cutters, except that they are of lighter construction. A hand screw feed tubing cutter of 1/8-inch to 1-1/4-inch capacity (fig 52) has two rollers with cutouts located off center so that cracked flares may be held in them and cut off without a waste of tubing. It also has a retractable reamer blade that is adjusted by turning a knob. Other types of tube cutters shown are designed to cut tubing up to and including 3/4 and 1 inch o. d. Some cutters have the feed screw covered to protect the threads against dirt and damage.

b. Use of tube cutters.

(1) Measurement. Measure tubing as you would pipe (para 15b(1)).

(2) Cutting tubing. The procedure for using a tube cutter is the same as for pipe cutters (para 15b(2)), except that a vise is not necessary. Tubing is held in one hand and the cutter rotated with the other hand. For large diameter tubing, using a vise is advisable. Be certain to use soft jaws on the vise to prevent damage to the tubing. Use the reamer blade, equipped with most tube cutters, to remove any burs from the inside diameter of the tube after it is cut.

c. Care of tube cutters. The care of pipe cutters discussed in 15c above is also applicable to the care of tube cutters.

17. FLARING TOOLS. Flaring tools are used to make single or double flares in the ends of tubing.

a. Types of flaring tools. Flaring tools (fig 55) are used to flare soft copper, brass, or aluminum to make up 45° flare joints. The single flaring tool consists of a split die block that has holes for 3/16-, 1/4-, 5/16-, 3/8-, 7/16-, and 1/2-inch o. d. tubing, a clamp to lock the tube in the die block, a yoke that slips over the die block that has a compressor screw, and a cone that forms a 45° flare or a bell shape on the end of the tube. The screw has a T-handle. A double flaring tool has the additional feature of adapters that turn in the edge of the tube before a regular 45° double flare is made. It consists of a die block with holes for 3/16-, 1/4-, 5/16-, 3/8-, and 1/2-inch tubing, a yoke with a screw and a flaring cone, plus 5 adapters for different size tubing; all carried in a metal case.

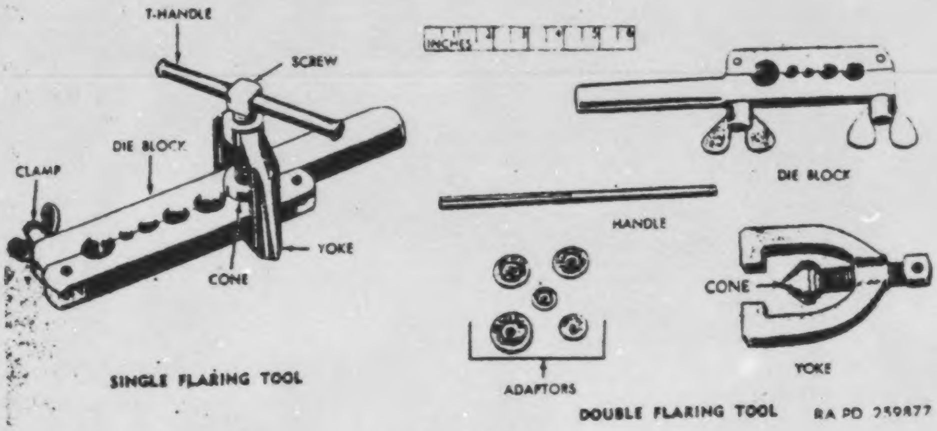


Figure 55. Flaring tools.

OS 424, 4-P45

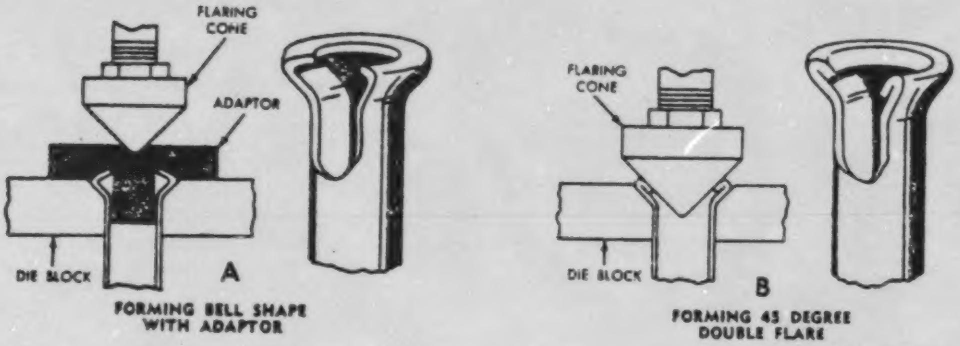
b. Use of flaring tool.

(1) Single flare. With the die block clamp screw (fig 55) loose, inset the tube in the corresponding size hole so that the tube extends approximately 1/8 inch above the face of the block. Tighten the clamp screw firmly to hold tube in place. Slide yoke over the end of the die block and turn the feed screw clockwise until the flaring cone forces the end of the tube tightly against the chamfer of the die block. The tube is now flared to a 45° angle. Back out feed screw, slide yoke off the die block, and loosen the clamp screw to remove the flared tube.

(2) Double flare.

(a) Insert tubing through the proper hole in the die block, with the end protruding above the block by the thickness of the shoulder on the appropriate adapter. Tighten the wingnuts on the die block and insert the adapter in the tubing. Move the yoke over the adapter and turn the feed screw clockwise until the shoulder of the adapter rests on the die block and a bell shape is formed on the tubing as shown in A, figure 56. Loosen the feed screw and remove the adapter from the tubing.

(b) Flare tube as you would for a single flare (B, fig 56).



FORMING BELL SHAPE WITH ADAPTOR

FORMING 45 DEGREE DOUBLE FLARE

RA PD 259880

Figure 56. Double flaring a tube.

c. Care of flaring tools.

(1) Read 15c above on the care of pipe cutters for general information on the care of flaring tools.

(2) Before storing, close the single flaring tool die block, install the yoke, and turn down the flaring cone until it just lightly touches an opening in the block. Return parts of the double flaring tool to their case after use.

SECTION II. MEASURING INSTRUMENTS

18. INTRODUCTION. Measuring tools are designed for measuring work accurately. They include level indicating devices (levels), noncalibrated measuring tools (calipers, dividers, trammels) for transferring dimensions or layouts from one medium to another, calibrated measuring tools (rules, precision tapes, micrometers) designed to measure distances in accordance with one of several standards of measurement, gages (go and no-go gages, thread gages) which are machined to predetermined shapes or sizes for measurement by comparison, and combination tools such as a combination square which is designed to perform two or more types of operation. In this section, measuring instruments will be discussed as to types, use, and care.

19. LEVELS. Levels are tools designed to prove whether a plane or surface is true horizontal or true vertical. Some levels are calibrated so that they will indicate the angle inclination in relation to a horizontal or vertical surface in degrees, minutes, and seconds.

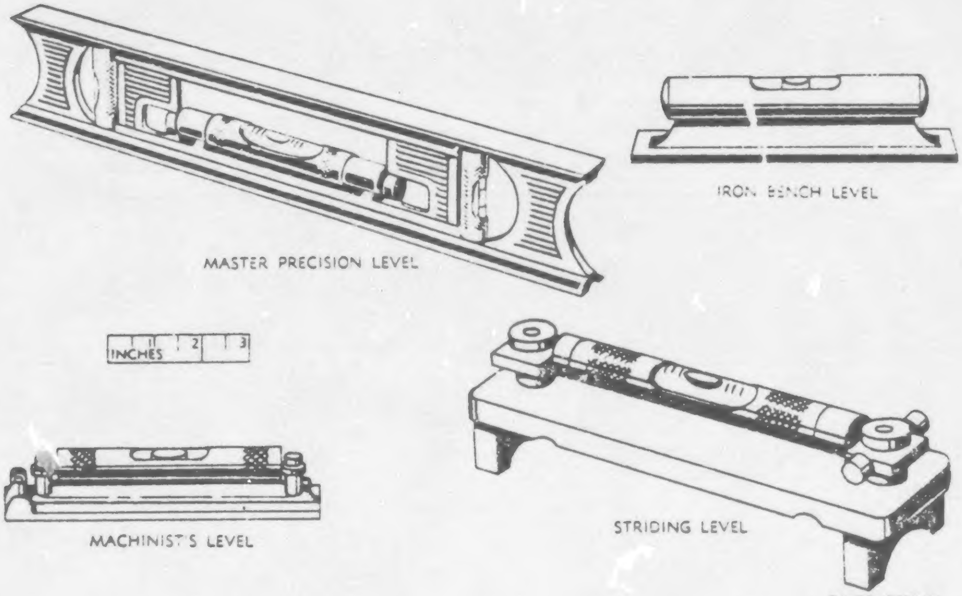
a. Types of levels. The level is a simple instrument (fig 57) consisting of a liquid sealed in a glass tube. The tube is mounted in a frame which may be of aluminum, iron, or wood. Aluminum levels, light in weight, will not rust. Wood levels are light and are not cold to the touch when used outdoors in cold weather. Iron levels, which are heavier and which will rust, hold their shapes better and withstand more abuse than either wood or aluminum levels. Levels are equipped with one, two, or more vials (glass tubes). One set of tubes is built in the frame at right angles to the other set, with an air bubble in each tube.

(1) Master precision level. The master precision level has an accurately ground and graduated main vial of 10-second accuracy; one division equals 0.00058 inch per foot. This accuracy refers to the arc of the vial. Sixty seconds equal 1 minute of arc and 60 minutes equals 1° of arc. The master precision level aids in setting true horizontal while being held horizontally on the surface. This level is equipped with two additional shorter tubes at right angles to the main vial. These serve in setting the true vertical, while the level is being held at the side of the surface. The top and bottom of the level is milled and ground to make both surfaces absolutely parallel.

(2) Machinist's levels. Levels of this type come in various sizes with adjustable ground glasses and graduated vials with cross levels. The adjustable ground glasses are extra long and of large diameter arc, making them a sensitive and accurate level for machinists' use. Some of these levels have grooved bottoms, making them particularly valuable for leveling shafting, pipes, and so forth.

(3) Iron bench levels. Iron bench levels are commonly used by machinists, plumbers, millwrights, electricians, and in all forms of construction. They are made of strong castings of special construction which insure lightness, strength, and rigidity. They all have ground and graduated vials.

(4) Striding levels. Striding levels are machinist's bench levels specially adapted for spanning over obstructions. The vial is mounted on a support that has two legs. The legs are machined concave in the center to span obstructions, such as a pipe that runs parallel to the surface being checked. The raised support provides the necessary room to clear obstructions, such as the V-ways on a lathe when checking true horizontal of the flatways on a lathe.



RA PD 257482

Figure 57. Types of levels.

b. Mechanics of levels. The vials or glass tubes used in levels today are either bent or ground.

(1) Bent glass tube vials are made from glass tubing and are slightly curved in an arc so that the high point is exactly in the center. The bubble in a bent glass vial settles quickly but with sufficient accuracy for carpenters' and masons' work.

(2) Ground vials are also made of glass tubing, straight on the outside, but with the inside ground barrel shaped so that the high point is in the center. The bubble in a ground vial works slower, but is extremely accurate.

c. Using the level (fig 58).

(1) Checking for true horizontal. Choose the longest level most convenient for the job. After positioning the level horizontally on the work, note the vial or graduated tube for proper indication. Ground glass vials usually have 2 or more etched lines on the glass. For true horizontal, the bubble should be centered between lines; on graduated vials, the proper indication is dependent on the accuracy required. The bubble should be centered between divisions on the vial that indicate the desired position of the work.

(2) Checking for true vertical. With the level placed vertically against the work, check for true vertical (plumb) by observing the position of the cross-vial bubble. The bubble should be centered between lines on the vial.

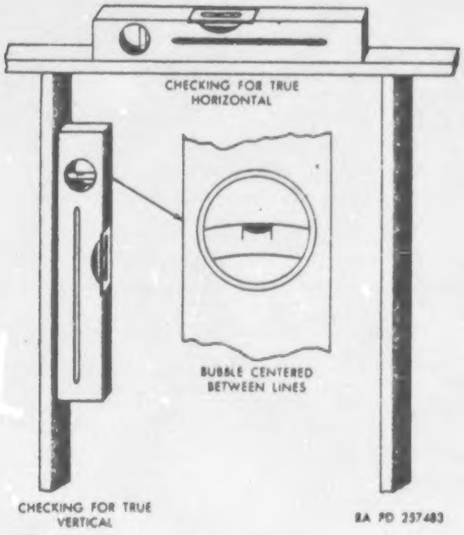

CHECKING FOR TRUE HORIZONTAL
BUBBLE CENTERED BETWEEN LINES
CHECKING FOR TRUE VERTICAL
RA PD 257483

Figure 58. Horizontal and vertical use of the level.

d. Care of levels.

(1) Test. Place the level on a true horizontal surface and note the vial indication. Reverse the level end for end. If the bubble appears on one side of the markings with reference to the operator on the first reading and on the other side for the second reading, the level is out of true. Place the level against a true vertical surface to check for vertical accuracy. Take a reading. Twist the level one-half turn about its vertical axis and reread. If the bubble appears on the opposite side of the hairline with reference to the operator, the level is out of true.

(2) Adjustments. On adjustable-type levels, turn the adjusting screw or nut to move the vial in the desired direction. Tighten adjustment and retest on a true horizontal surface. The bubble should be centered between markings on the vial. On nonadjustable metal framed levels, remove the vial-attaching hardware and shim the necessary end of the vial so that when retested the bubble is centered and is true. On nonadjustable wood framed levels, remove the vial from the frame. Set the level on a true horizontal surface; spread calcined gypsum and water mixture for a vial tube bed; position the vial so that the bubble is centered. Allow gypsum to set before removing the level.

(3) Maintenance. Use levels with caution—do not drop, handle roughly, or use for purposes other than those intended. When not in use, store levels in a rack or other suitable place to prevent damage. Make certain the storage place is dry. Spread a thin film of rust-preventive compound or oil on all metal parts before storage. Remove rust-preventive compound by washing with a suitable cleaning solvent before reusing.

OS 424, 4-P49

20. SCRIBERS. Scribers are used to mark and lay out a pattern of work to be followed in subsequent machining operations, and are made for scribing, scoring, or marking many different materials such as glass, steel, aluminum, and copper.

a. Types of scribers.

(1) Machinist's scribers. Machinist's single point pocket-type scribers (fig 59) have a scriber point made of tempered high-grade steel and a handle of steel tubing that is nickel plated. The point is reversible, telescoping into the knurled handle when not in use. This type scriber usually has a 1/4- or 3/8-inch diameter handle with a point length of 2-3/8 or 2-7/8 inches. Bent point scribers are usually 8 to 12 inches long with one straight point, and one long or one short bent point. Some of these scribers are threaded and can be engaged in either end of the handle. The long bent point is designed for reaching through holes beyond a lip or ridge. Portions of these scribers are knurled for firm grip.

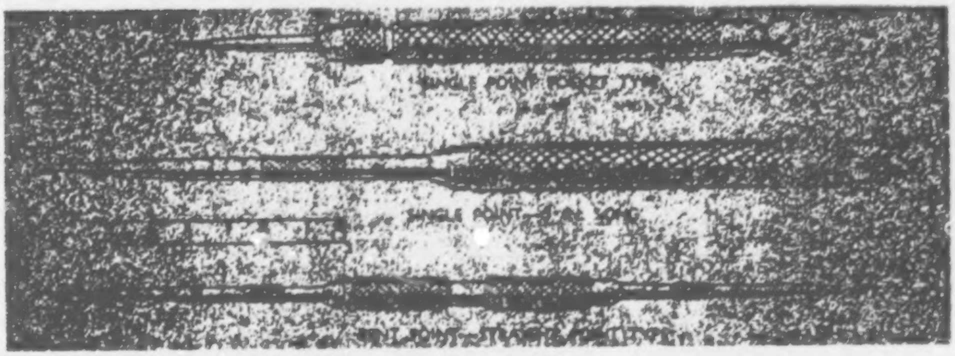


Figure 59. Types of machinist's scribers.

(2) Tungsten carbide scribers. These scribers are used to lay out lines on very hard materials, such as hardened steel and glass. The scriber point is made of tungsten carbide, a long wearing material, which makes it possible to scribe sharp, well defined lines on the hardest materials. Some of these scribers are used with an extension in conjunction with a vernier height gage which allows reverse measurements to be taken from the top of the bottom side of the gage jaw. This type scriber is hardened, ground, and lapped to a point so that a line or series of lines may be drawn and spaced as required in the laying out of dies and so forth.

b. Using the scribers.

(1) Make sure the point of the scriber is sharp. To sharpen, rotate the scriber between thumb and forefinger while moving the point back and forth on an oilstone.

(2) Clean work surfaces of all dirt and oil.

(3) Place the steel rule or straightedge on the work beside the line to be scribed.

(4) Use the fingertips of one hand to hold the rule in position and hold the scriber in the other hand as you would a pencil (fig 60).

(5) Scribe the line by drawing the scriber along the edge of the rule, at a 45° angle and tipped outward and slightly in the direction it is being moved.

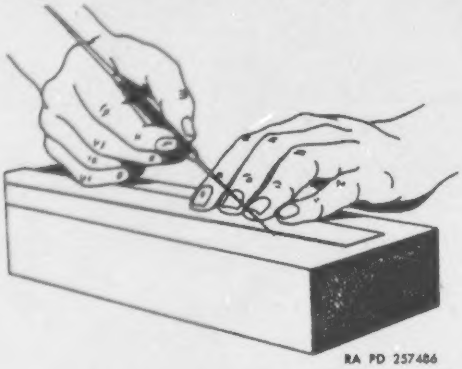


Figure 60. Using the scriber.

c. Care of scribers. Place a cork or soft wood over the point of the scriber when not in use. Coat scriber with rust-preventive compound before storage. Do not throw scribers in a drawer with other tools. This practice can cause damage to scribers and injury to personnel. Rack properly or stow in suitable box. Do not use scribers for purposes other than those intended.

21. RULES. All rules (scales) are used to measure linear dimensions. They are read by a comparison of the etched lines on the scale with an edge or surface. Most scale dimensions are read with the naked eye, although a magnifying glass can be used to read graduations on a scale smaller than 1/64 of an inch.

a. Types of rules.

(1) Steel rules. Steel rules (fig 61) are available from a fraction of an inch in length up to 4 feet or more, but in machine shops the 6-inch pocket rule is the one most commonly used. There are also several standard systems of graduations. In the English system, rules are graduated in 10ths, 20ths, 50ths, and 100ths; 12ths, 24ths, and 48ths; 14ths, and 28ths, and 16ths, 32ds, and 64ths of an inch. In the Metric system, rules are graduated in millimeters and one-half millimeters. Some steel rules have four scales, two on each side (one graduated in 32ds and the other in 64ths), with the scales on the reverse side running in the opposite direction. There are rules made that have both an inch scale and millimeter scale, which makes this type rule adaptable to work involving both systems of measure. Another feature on some rules is a scale etched across the end of the rule which facilitates measurement in restricted places.

(a) Flexible rule. A flexible rule (fig 61) is made of thin, tempered spring steel which permits it to be bent over a rounded surface.

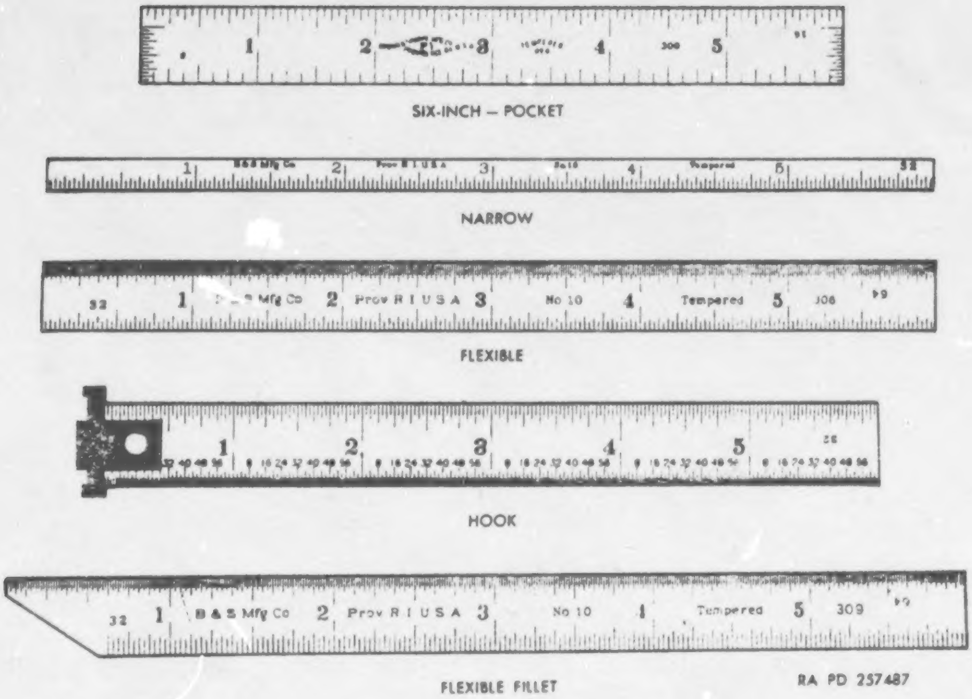


Figure 61. Types of steel rules.

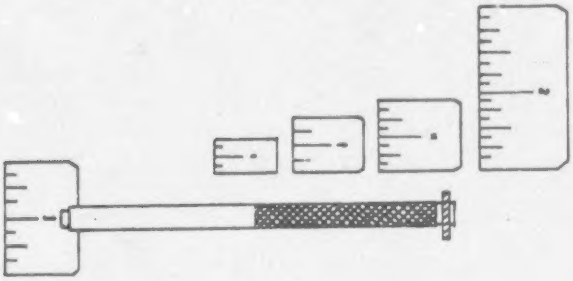


Figure 62. Short rules and holder.

(b) Hook rule. A hook rule (fig 61) has a sliding hook which facilitates measuring from a shoulder, particularly if the end of the rule is hidden so that it cannot be lined up with the shoulder. The sliding hook is also convenient in setting calipers and dividers.

(c) Short rules and holders. Short rules with a holder (fig 62) are available for measuring in a recess or in a restricted area.

(d) Flexible fillet rule. A flexible fillet rule (fig 61) is used to span fillets and corner fills which are frequently in the way when measuring flanges, shoulders, and so forth.

(e) Key seat clamps. Key seat clamps (fig 63) are made of steel, case-hardened, and weight 1 ounce each. They are designed to transform and straight steel rule into a rule that can be used to lay out keyways on a cylindrical surface of a shaft.

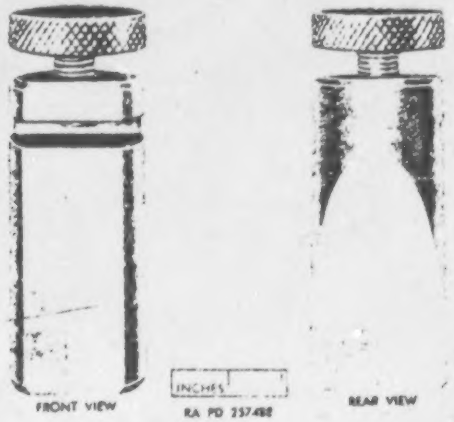
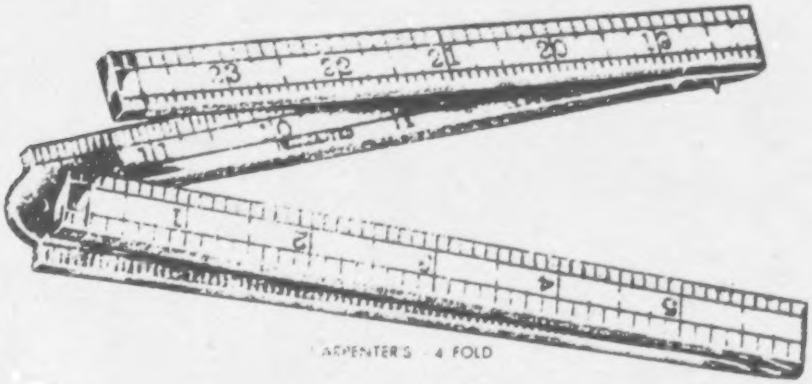
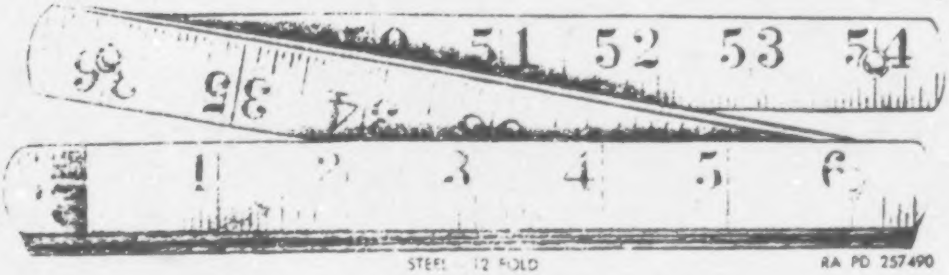

FRONT VIEW
INCHES
RA PD 257488
REAR VIEW

Figure 63. Key seat clamp.

(2) Folding rules. Folding rules (fig 64) are obtainable in wood or metal, having 4 to 12 folds, from 2 to 6 feet long total length. These rules cannot be relied on for extremely accurate measurements because a certain amount of play develops at the joints after they have been used for a time.


23
22
21
20
19
1
2
3
4
5

CARPENTER'S - 4 FOLD


36
35
34
50
51
52
53
54
1
2
3
4
5
6

STEEL - 12 FOLD RA PD 257490

Figure 64. Types of folding rules.

OS 424, 4-P53

(3) Circumference rule. The circumference rule (not illustrated) supplied by Army ordnance is 36 inches long, 1-1/4 inches wide, 1/16 inch thick. Both sides are marked with graduations of 1/16 inch on one edge and 1/8 inch on the opposite edge. This rule is capable of measuring a 36-inch diameter and 113 inches maximum circumference reading, using a conversion scale.

b. Using the rule.

(1) Select proper scale. When using a rule to check a dimension, the proper graduated scale should be used to control the reading of the dimension (A, fig 65). If the work being measured lines up between two graduations on the scale as shown in B and C, figure 65, and it is not possible to read this dimension to a 1/16 on a 1/16-inch scale, a 1/32-inch scale should be used, and if it is still impossible to read a dimension to a 1/32, a 1/64-inch scale should be used.

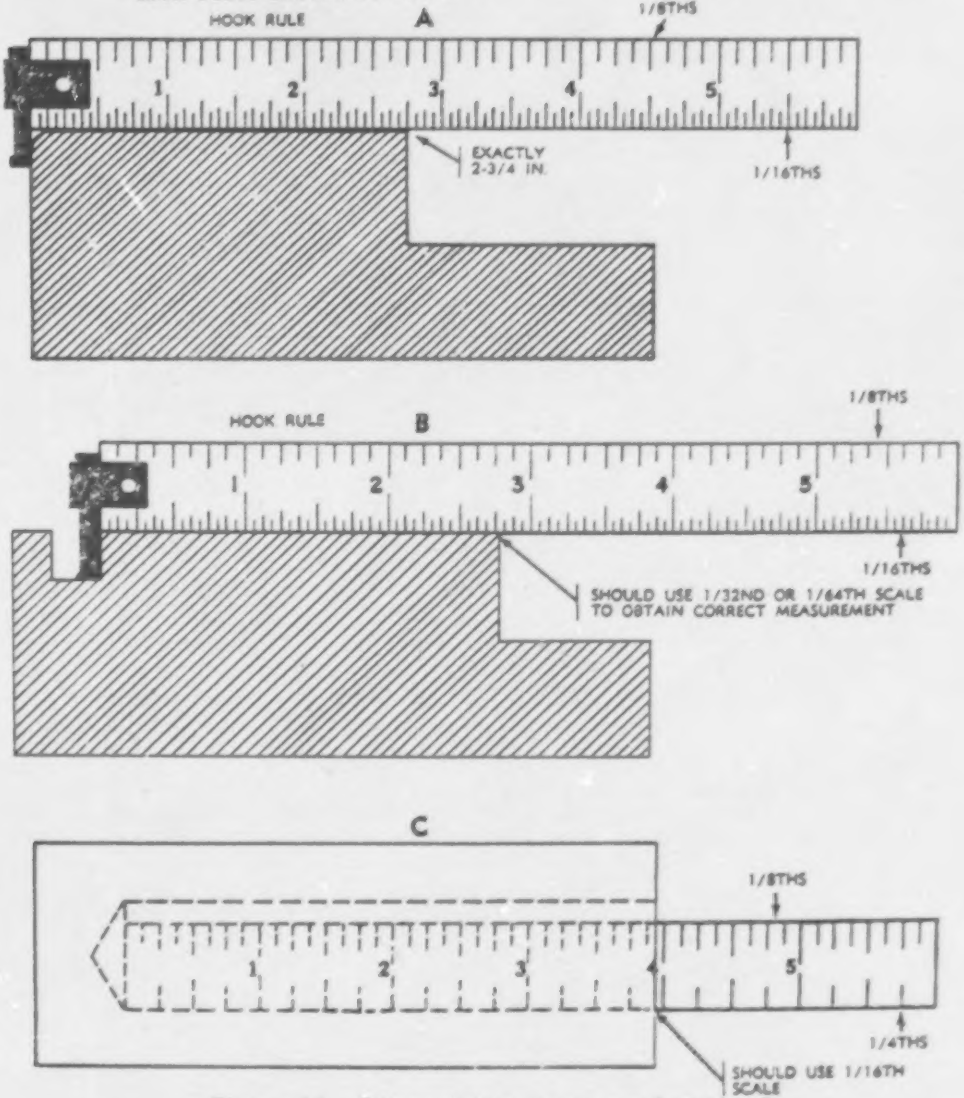

HOOK RULE
A
1/8THS
1
2
3
4
5
EXACTLY 2-3/4 IN.
1/16THS
HOOK RULE
B
1/8THS
1
2
3
4
5
1/16THS
SHOULD USE 1/32ND OR 1/64TH SCALE TO OBTAIN CORRECT MEASUREMENT
C
1/8THS
1
2
3
4
5
1/4THS
SHOULD USE 1/16TH SCALE

Figure 65. Determining proper graduated rule.

(2) Applications.

(a) Six-inch rule. It is good practice to carefully line up the end of the rule with the surface from which the measurement is to be taken. Figure 66 shows the mechanic holding the part and the rule firmly against an angle block. This allows the user to devote his entire attention to reading the scale correctly. Figure 67 illustrates the use of a rule in checking the location of a gaging surface from a surface plate. The surface plate in this case serves as a common base and locates the rule in relation to the surface on the part measured.

Note. - Always measure stock at right angles.

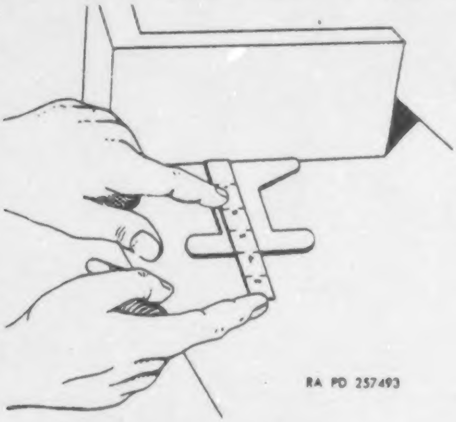


Figure 66. Using 6-inch rule.

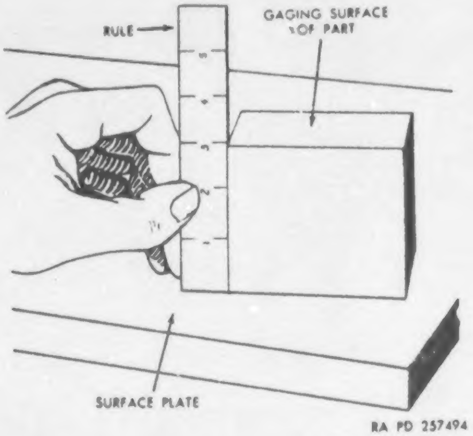


Figure 67. Using rule on surface plate.

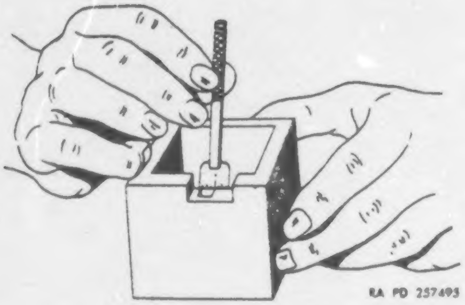


Figure 68. Using small rule and holder.

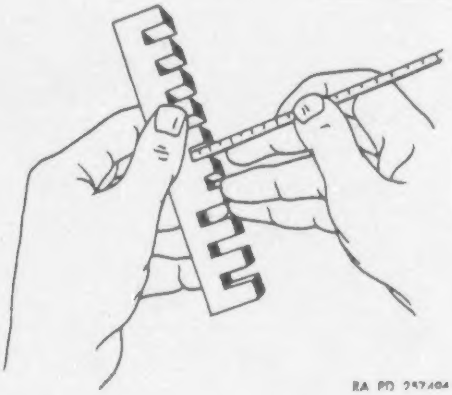


Figure 69. Using a narrow rule.

(b) Short rule and holder. Figure 68 shows how a short steel rule with holder may be usefully applied to a measurement in a recess inaccessible to the longer type rule.

(c) Narrow rule. The narrow rule is used to advantage in measuring the depth of a narrow slot (fig 69).

(d) Hook rule. Figure 65 shows applications of the hook rule. In one case, the hook serves to line up the end of the rule with the edge of the shoulder from which the measurement is taken; the other case shows the hook being used from the square edge of a part.

(e) Key seat clamps and rule. Figure 70 illustrates the method of scribing a line on cylindrical stock, using key seat clamps and rule.

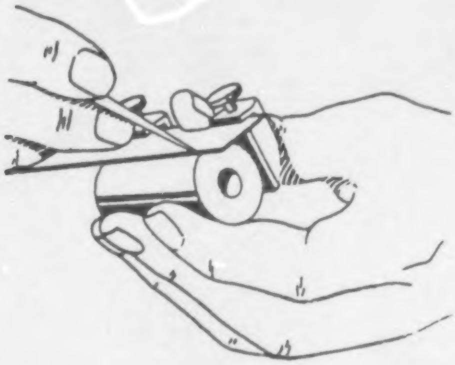


Figure 70. Using key seat clamps, rule and scriber.

c. Care of rules. Coat all steel rules with a rust-preventive compound or oil before storage. Make certain wood rules are stored in a dry place and are properly wrapped to preserve the wood. Clean rules before and after use, so that graduations are always legible. Periodically, check straightedges against a master surface plate for accuracy. The slightest nick will result in an incorrect reading. Do not use rules for purposes other than those intended.

22. TAPES. Tapes are used for measuring long distances and circumferences where rules cannot be applied.

a. Types of tapes (fig 71).

(1) Steel tape. Steel tapes are made from 6 to 100 feet in length. In the shorter lengths, they are frequently made with a curved cross section so that they are flexible enough to roll up, but remain rigid when extended. Long, flat tapes require support over their full length when measuring or the natural sag will cause an error in reading.

(2) Tape rule. The tape rule is a ribbon of flexible steel that is wound into a flat metal case by pressing a button or pushing it in by hand. A hook is provided at one end to hook over the object being measured so that one man can handle it without assistance. On some models, the outside of the case can be used as one end of the tape when measuring inside dimensions.

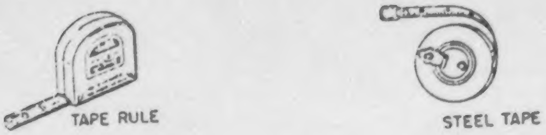

TAPE RULE
STEEL TAPE

Figure 71. Tapes.

b. Care of tapes.

(1) Tapes should be handled carefully and kept lightly oiled to prevent rust. Never allow the edges of measuring devices to become nicked by striking them with hard objects. They should preferably be kept in a wooden box when not in use.

(2) To avoid kinking tapes, pull them straight out from their cases—do not bend them backward. With the windup type, always turn the crank clockwise—turning it backward will kink or break the tape. With the spring-wind type, guide the tape by hand. If it is allowed to snap back, it may be kinked, twisted, or otherwise damaged.

23. SQUARES. The purpose of a square is to test work for squareness and trueness. It is also used as a guide when marking work for subsequent machining, sawing, planing, and chiseling operations.

a. Types of squares. There are several types of squares used in woodwork and metalwork.

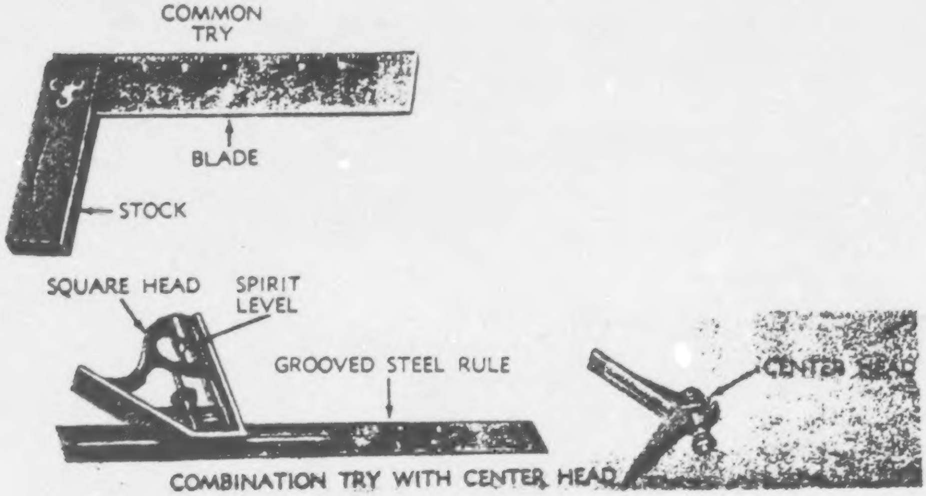

COMMON TRY
BLADE
STOCK
SQUARE HEAD
SPIRIT LEVEL
GROOVED STEEL RULE
CENTER HEAD
COMBINATION TRY WITH CENTER HEAD

Figure 72. Types of squares.

(1) Try square. The common try square (fig 72) consists of two parts at right angles to each other: a thick wood or iron stock and a thin steel blade. The best try squares are made with the blades graduated in inches and fractions of an inch. The blade length varies from 2 inches to 12 inches. This square is used for setting or checking lines or surfaces which have to be at right angles to each other.

(2) Combination squares or sets.

(a) The combination try square shown in figure 72 consists of a square sliding head and a grooved steel rule. The square head has a spirit level. The steel rule usually has four graduated scales: 1/64, 1/32, 1/16, and 1/8 inch. The rule is removable, permitting the head to be used as an ordinary level. It is possible to use this combination square to square a piece with a surface and, at the same time, determine whether one or the other is plumb. By using the miter, it is possible to lay out 45° and 90° angles. This square can also be used as a depth gage.

(b) By adding a center head on the combination try square, another combination is formed. By substituting the center head for the square head, a center square is obtained for finding the centerline of cylindrical objects. The center head is slotted so that the rule, when inserted, bisects the 90° angle. When used this way, the measuring surfaces become tangent to the circumference of cylindrical work.

(c) The combination square set shown in figure 73 includes a protractor in addition to the square and center heads. The protractor can be inserted in the steel rule in the same manner as the square and center heads. The revolving turret can be graduated in degrees from 0 to 180 or to 90 in either direction. The square head contains a spirit level to facilitate the measuring of angles in relation to the horizontal or vertical plane. The protractor controls the accuracy of measuring and laying out angles within 1°. Some protractor heads have a shoulder extending from only one side of the blade, and these are known as "single," "plain," or "not reversible." Others have a shoulder extending from both sides and are known as "double" or "reversible" protractors. This combination square set takes the place of a whole set of common tools capable of serving as a height gage, bevel protractor, level, steel rule, depth gage, marking gage, and plumb.

(3) Bevel protractor. A bevel protractor (fig 74) consists of an adjustable blade with a graduated dial. The blade is usually 12 inches long and 1/16 inch thick. The dial is graduated in degrees through a complete circle of 360°. This protractor is equipped with an acute angle attachment which is used in measuring extremely small angles.

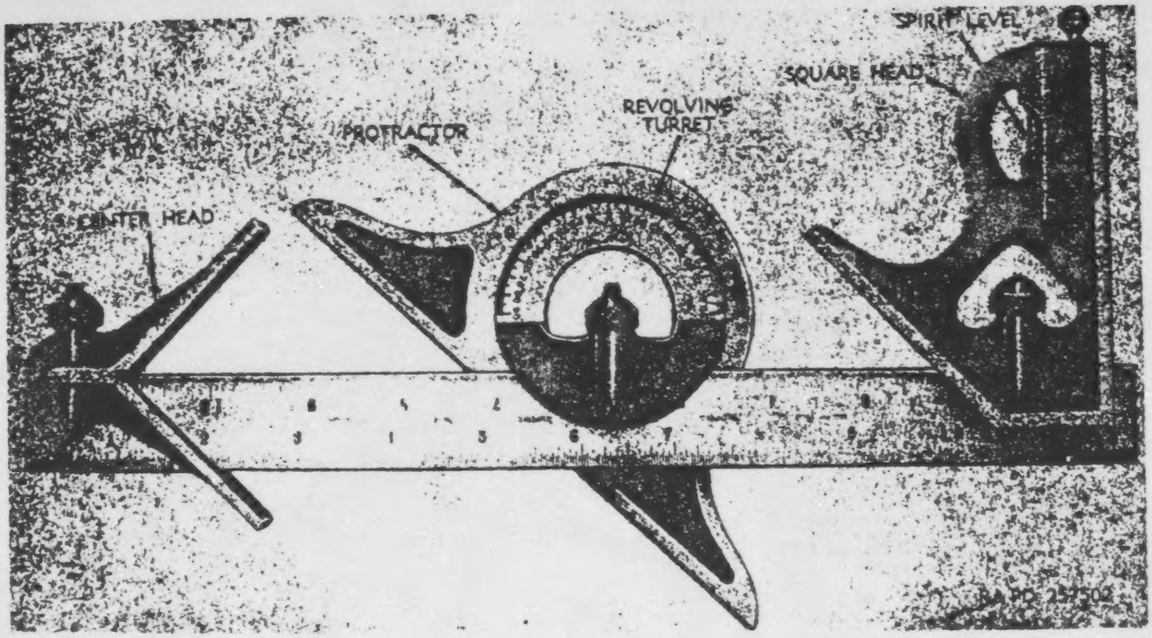

SPIRIT LEVEL
SQUARE HEAD
REVOLVING TURRET
PROTRACTOR
CENTER HEAD
RA PD 257502

Figure 73. Combination square set.

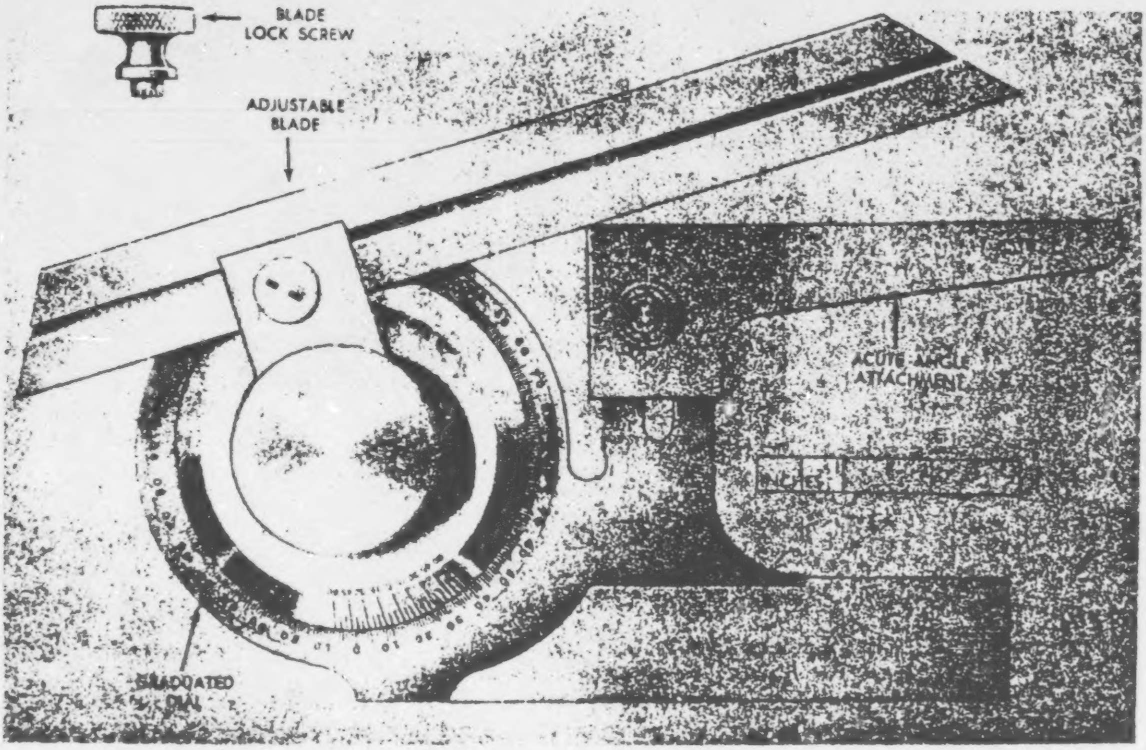

BLADE LOCK SCREW
ADJUSTABLE BLADE
ACUTE ANGLE ATTACHMENT
INCHES
GRADUATED DIAL

Figure 74. Bevel protractor.

b. Use of squares.

(1) Try square.

(a) The try square is used constantly for laying out and to determine whether edges and ends are true with adjoining edges and with the face of the work after it has been sawed, planed, or chiseled. Figure 75 illustrates several uses of the try square where faces have to be at right angles to each other. A reference plane such as a surface plate or a machined, sawed, planed, or chiseled surface of the work is essential to its use. As shown in E, figure 75, a thickness or feeler gage is used to check the squareness of a surface which cannot touch the blade of the square. When the try square allows no light to show (A and B, fig 75), work is square and true. When light shows (C and D, fig 75), work is not square.

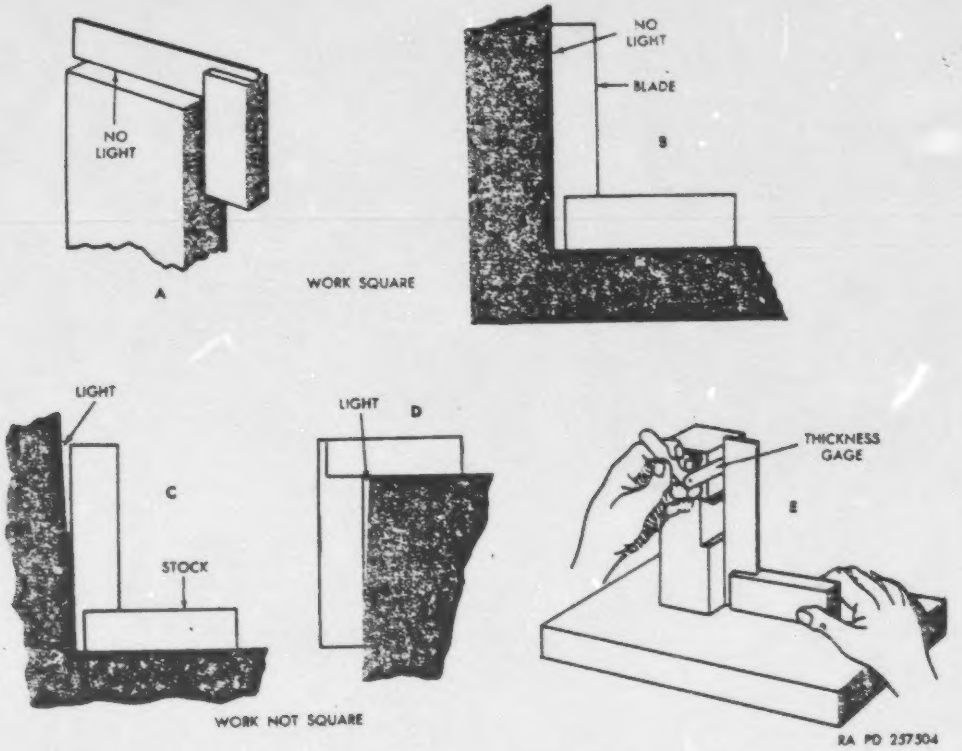
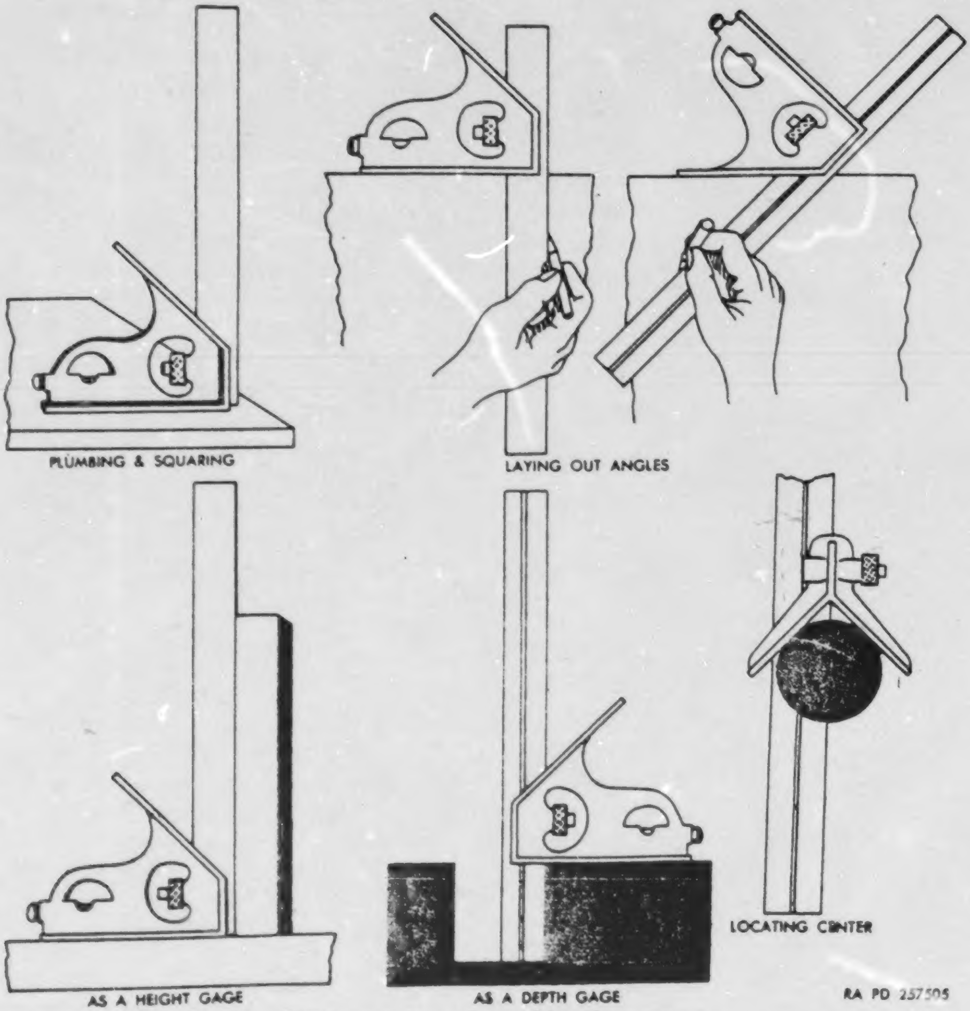


Figure 75. Using a try square.

(b) When a board is to be cut, planed, or chiseled square, a guideline must be marked across its surface. The guideline must be exactly at the required point and must be square with the edges. If the board is too wide for the try square, use the carpenter's square. Press the stock of the try square firmly against the edge of the board with one hand and mark the guideline along the blade with a pencil in the other hand.

(c) To square a line around a board, mark one edge and one face of the board with an X so that they can be distinguished readily as the working edge and face. Square a line from the working edge across the face by holding the stock of the square firmly against the working edge and marking a line across the face. Then square a line across each edge; turn the board over and square a line across the opposite face. The edge of the board must be perfectly square to prevent the square from rocking. Use a carpenter's square if the board is too wide for a try square.

(2) Combination square. Figure 76, illustrates various applications of a combination square. Loosen the knurled nut on the head and slide the head along the blade to the desired position. Tighten nut and place the particular head and blade in position on the work. As illustrated, the combination square is a versatile unit having many varied uses. Figure 77 shows the protractor head being used to check the angle of a lathe way. By setting the head at a definite angle, the variation can be measured by using thickness or feeler gages between the blade and the face of the way.


PLUMBING & SQUARING

LAYING OUT ANGLES

AS A HEIGHT GAGE

AS A DEPTH GAGE

LOCATING CENTER

RA PD 257505

Figure 76. Various uses of combination square.

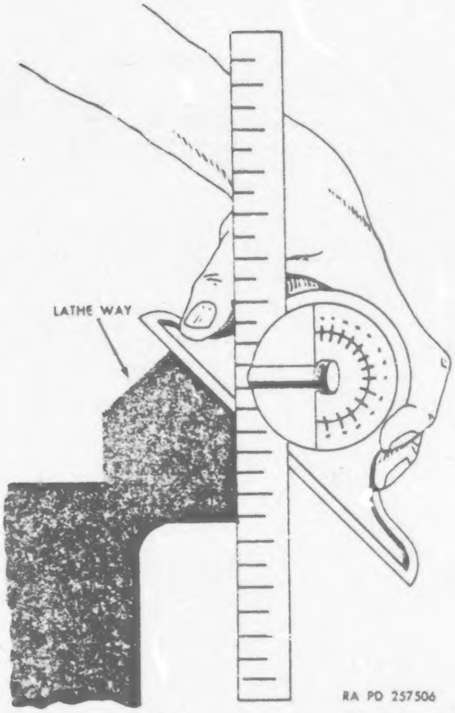


Figure 77. Using protractor head.

(3) Bevel protractor. Laying out precision angles is the primary function of this tool. The tool can be laid flat upon paper or work. The vernier scale is used for accurate angle adjustments, and reads to 5 minutes or 1/12°. The dial is held rigidly in position and the blade can be moved back and forth and clamped independently of the dial.

(a) Reading the protractor vernier scale. The protractor vernier scale indicates every 5 minutes (5') or 1/12°. Each space on the vernier scale is 5 minutes less than two spaces on the main scale. When the zero on the vernier scale exactly coincides with a graduation on the main scale, the reading is in exact degrees, as shown in A, figure 78. When the zero of the vernier scale does not exactly coincide with a graduation on the main scale, the graduation on the vernier that does coincide indicates the number of 12ths of a degree or units of 5 minutes to be added to the whole degree reading. Example: Reading in B, figure 78, shows the zero on the vernier between 12° and 13° on the main scale. Counting to the right from 0 on the main scale, the 0 on the vernier has therefore moved 12 whole degrees. Reading in the same direction (to the right), note that the 10th line of the vernier exactly coincides with a line on the main scale. The 10th line of the vernier indicates 50 minutes (50'), since each line indicates 5 minutes. Now add 50 minutes to the 12° and the final reading is 12° 50 minutes. Since the spaces, both on the main scale and on the vernier scale, are numbered both to the right and left from zero, any size angle can be measured. The readings can be taken either to the right or left, according to the direction in which the 0 on the vernier scale is moved.

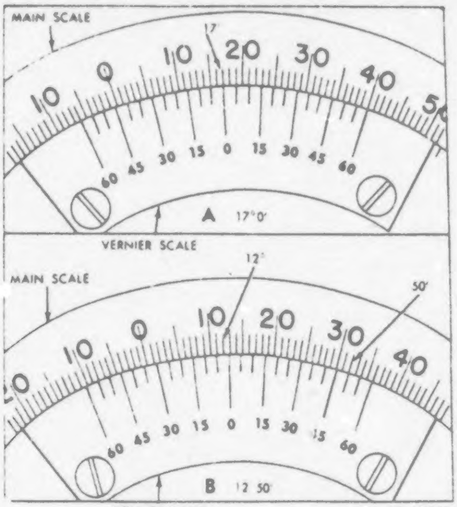

MAIN SCALE
17°
10
0
10
20
30
40
50
60
45
30
15
0
15
30
45
60
A 17°0'
VERNIER SCALE
MAIN SCALE
12°
50'
20
10
0
10
20
30
40
60
45
30
15
0
15
30
45
60
B 12°50'
VERNIER SCALE
RA PD 257507

Figure 78. Protractor vernier scale readings.

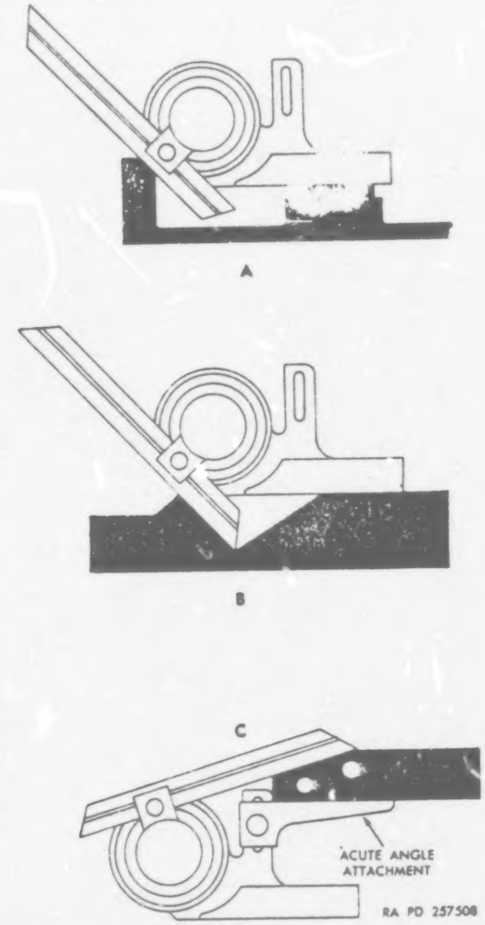

A
B
C
ACUTE ANGLE ATTACHMENT
RA PD 257508

Figure 79. Using bevel protractor.

(b) Application. A, figure 79, shows the bevel protractor being used to measure the angular clearance on a ring gear. The bevel protractor can be used to establish an angle and determine its relationship to other surfaces as shown in B, figure 79. The acute angle attachment is attached to the slotted extension of the dial and is used as shown in C, figure 79, to accurately measure acute angles.

c. Care of squares. Make certain the blades, heads, dials, and all accessories are kept clean. Apply a light coat of oil on all machined surfaces to prevent rusting when not in use. Do not use try squares or miter heads for purposes other than those intended. A try square with a loose handle is a useless tool. When storing squares or bevels for long periods of time, apply a liberal amount of oil or rust-preventive compound to all surfaces, wrap in oiled paper, and place in individual containers or on racks.

24. DIVIDERS. Dividers are used for measuring distances between two points, for transferring or comparing measurements directly from a rule, or for scribing an arc, radius or circle.

a. Types of dividers.

(1) Spring divider. A spring divider (fig 80) consists of two sharp points, at the end of straight legs, held apart by a spring and adjusted by means of a screw and nut. The spring divider is available in sizes from 3 to 10 inches in length.

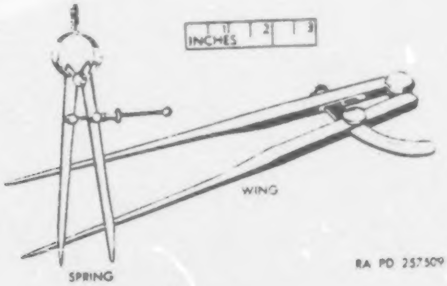


Figure 80. Dividers.

(2) Wing divider. A wing-type divider (fig 80) has a steel bar that separates the legs, a locking nut for securing a rough measurement, and an adjusting screw for fine adjustments. The wing-type divider is available in 6-, 8-, and 12-inch lengths. An improved version of this type has the tip of one leg removable so that a pencil can be inserted.

b. Use of dividers. In setting a divider to a dimension on a scale, the usual procedure is to locate one point in one of the inch graduations of the rule and to adjust the nut or screw so that the other point falls easily into the correct graduation (A, fig 81).

Note. - Do not set to end of rule.

Make certain the points of the divider are not blunt (B, fig 81). When transferring a dimension from a part or tool to the scale on a rule, use the same care in adjusting the points of the dividers, making sure that there is no pressure tending to spring the points either in or out. Illustrated in C, figure 81, is a mechanic scribing a radius on a die block he is laying out.

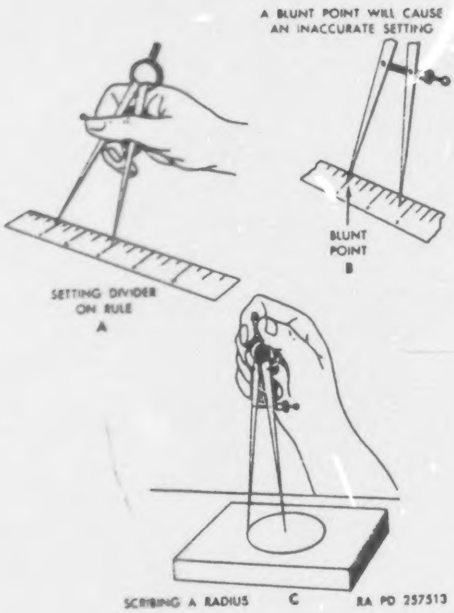


Figure 81. Using dividers.

c. Care of dividers. Never use a divider for a purpose other than that for which it was intended. Never pile these tools in a drawer. Never force dividers beyond their capacity or setting. Never use these tools incorrectly—changing settings by hammering instead of loosening a clamping screw or nut, bearing down too hard when scribing with a divider, or wearing measuring surfaces unnecessarily by using a heavy measuring pressure. Apply a protective film of oil to tools when not in use.

25. CALIPERS. Calipers are used for measuring diameters and distances, or for comparing dimensions or sizes with standards such as a graduated rule.

a. Types of calipers.

(1) Outside calipers. Outside calipers (fig 82) are used to measure distances over and around adjacent surfaces and to transfer the measurements to a rule. Several types are made in different sizes to accommodate a wide range in measurements. The size of the caliper is expressed in terms of the maximum dimension it is capable of measuring. A 3-inch caliper, for example, will measure a distance of 3 inches. Actually, the maximum capacity of the caliper will be greater, often as much as one-third. This means that a 3-inch caliper will actually measure up to 4 inches; however, it is not recommended that you use a 3-inch caliper to measure 4 inches, since you may spring the legs resulting in an inaccurate measurement.

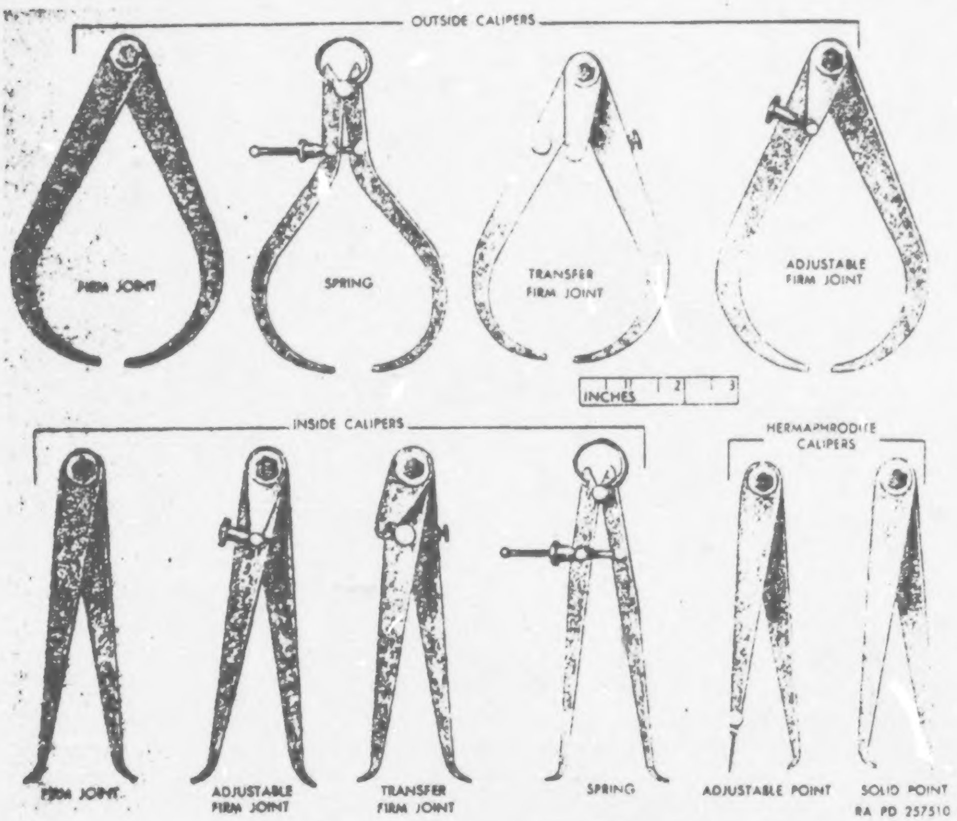

OUTSIDE CALIPERS
FIRM JOINT
SPRING
TRANSFER FIRM JOINT
ADJUSTABLE FIRM JOINT
INCHES
1
2
3
INSIDE CALIPERS
HERMAPHRODITE CALIPERS
FIRM JOINT
ADJUSTABLE FIRM JOINT
TRANSFER FIRM JOINT
SPRING
ADJUSTABLE POINT
SOLID POINT
RA PD 257510

Figure 82. Calipers—noncalibrated.

(2) Inside calipers. Inside calipers (fig 82) have the same general function as outside calipers, except, that where the latter are used in measuring distances over outside surfaces, the inside caliper is used in measuring distances between inside surfaces. The points are rounded so that they are slightly ball-shaped. This ball shape establishes the point of contact, and in inside calipering where the surfaces are likely to have an inside curvature an error may occur if the radius of the hole being calipered is less than the radius of the points. Some inside calipers are equipped with an adjusting screw on one leg which provides a fine adjustment of the caliper legs.

(a) Spring caliper.

1. The spring caliper is available in sizes from 2 to 8 inches. The friction of the adjusting nut and screw works against the tension of the spring which holds the legs in any set position. This type of inside caliper is known as the toolmaker's spring caliper.

2. Thread spring calipers are used to measure diameter and distances in tapped holes. The ends of the legs of thread calipers are shaped to a fine point so that exact contact may be made between threads.

(b) Firm joint caliper. The firm joint type is available in a number of sizes from 3 to 24 inches. This type of caliper is equipped with a nut and stud that provides sufficient friction to hold the legs in any set position. Some of this type caliper are equipped with an adjusting screw for fine adjustments.

(c) Transfer firm joint caliper. Inside transfer firm joint calipers are shaped for inside measurements and are used for measuring recesses where the seting cannot be transferred to a scale directly because the legs must be collapsed to remove them from the work.

(3) Hermaphrodite calipers. Hermaphrodite calipers (fig 82) are a cross between a divider and an inside caliper, having one leg of each. These calipers are used for scribing parallel lines from an edge or for locating the center of cylindrical work. Some are equipped with an adjustable point.

(4) Trammels. A trammel is a tool used for the same purposes as a divider or caliper, but usually for distances beyond the range of either of these two instruments. A steel beam trammel with all of the attachments required in measuring and layout work is shown in figure 83. The instrument consists of a rod or beam to which trams may be clamped. These steel beams will range in length from 9 to 20 inches, but may be increased further through the use of extensions. Longer beams are often made of wood. The trams carry spring chucks in which divider points, caliper points, and ball points may be inserted so that the trammel may be readily converted from a divider to an outside or inside caliper or to a hexmaphrodite caliper. Ball points are used to position a tram in the center of a hole. By using different size balls or V-points, it is possible to position the tram in any size hole up to 1-1/2 inches in diameter. On top of the trams are knurled handles which swivel so that the handles may be gripped firmly when describing a circle or an arc. An adjusting screw is provided on one of the trams which permits a fine adjustment of the points.

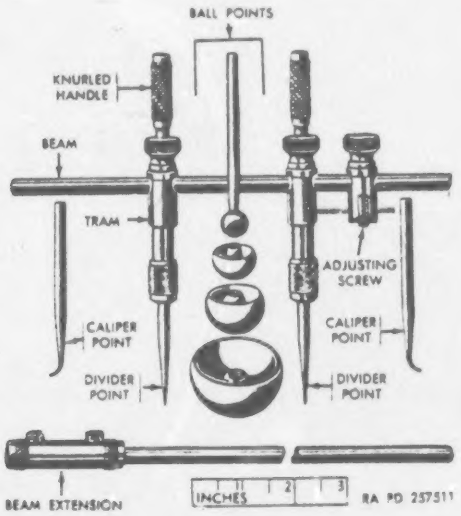


Figure 83. Trammel set.

(5) Vernier calipers. This type of caliper utilizes the vernier scale. The vernier scale consists of a short auxiliary scale usually having one more graduation in the same length as the longer main scale. The vernier caliper (fig 84) consists of an L-shaped frame, the end of which is a fixed jaw; the long arm of the L is inscribed with the main true scale or fixed scale. The sliding jaw carries the vernier scale on either side. The scale on the front side is for outside measurements; the scale on the back is for inside measurements. On some vernier calipers, the metric system of measurement is placed on the back side of the caliper in lieu of a scale used for inside measurements. In such cases, you must add the thickness of the nibs to the reading when making inside measurements. The tips of the jaws are formed so that inside measurements can be taken. The thickness of the measuring points is automatically compensated for on the inside scale. The length of the jaws will range from 1-1/4 inches to 3-1/2 inches, and the minimum inside measurement with the smallest caliper is 1/4 inch or 6 millimeters. Vernier calipers are made in standard sizes of 6, 12, 23, 36, and 48 inches, and 150, 300, 600, and 900 millimeters. The jaws of all vernier calipers, except the larger sizes, have two center points, which are particularly useful in setting dividers to exact dimensions.

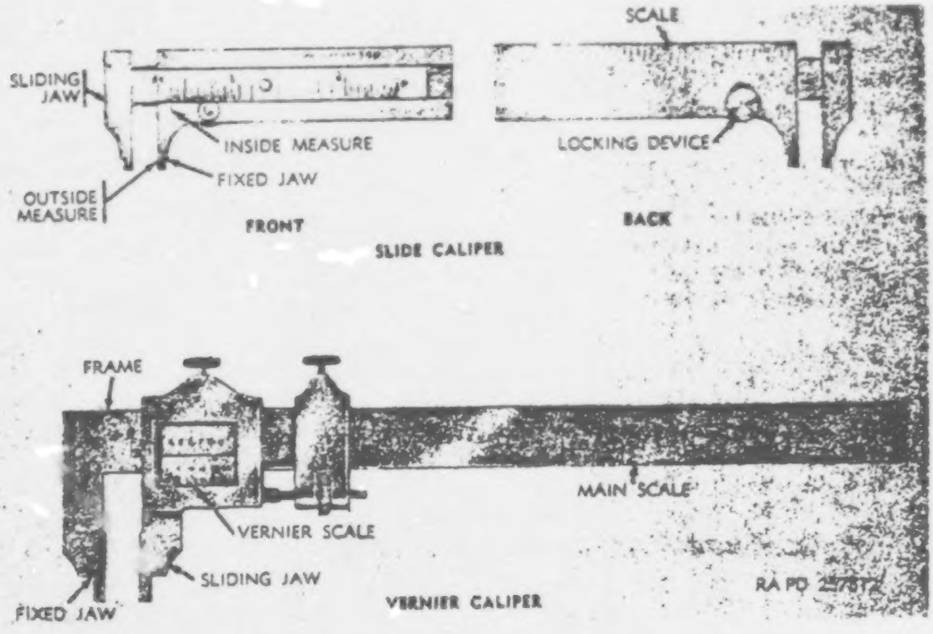


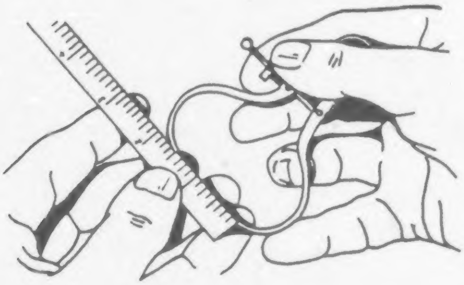
Figure 84. Calipers—calibrated.

(6) Slide caliper. The slide caliper (fig 84) has one fixed jaw and one sliding jaw. When the two jaws are brought in contact with surfaces to be measured, the distance between the surfaces may be read from the scale. The ends of the jaws are so shaped that it is possible to measure both inside and outside surfaces. Slide calipers are usually made in 3-inch sizes, although larger size calipers are available. The standard 3-inch slide caliper will measure from 0 to about 2 inches outside, and from 1/8 inch to a little more than 2 inches inside. The caliper shown has a mark or graduation line on the fixed jaw which enables the user to read the inside

measure, while the outside measure can be read from the inner edge of the fixed jaw directly. If these marks were not on the slide caliper, it would be necessary to add the thickness of the nibs to the reading when using it as an inside caliper. All slide calipers are equipped with a locking device which makes it possible to hold the jaws in any desired position.

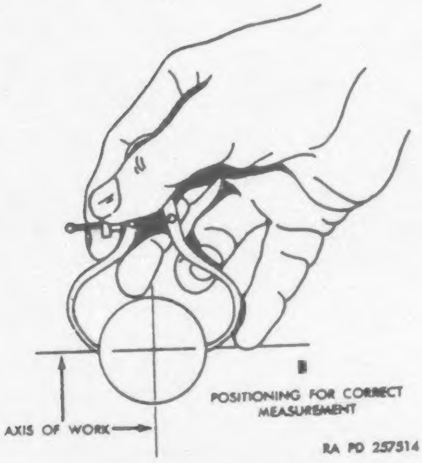
b. Use of calipers.

(1) Outside calipers. A caliper is usually used in either of two ways. Either the caliper is set to the dimension of the work and the dimension transferred to a scale, or the caliper is set on a scale and the work machined until it checks with the dimension set up on the caliper. To adjust an outside caliper to a scale dimension, one leg of the caliper should be held firmly against one end of the scale and the other leg adjusted to the desired dimension, as shown in A, figure 85. To adjust the outside caliper to the work, open the legs wider than the work and then bring them down to the work. A sense of feel must be acquired to use calipers properly. This comes through practice and care in using the tool to eliminate the possibility of error. Always position the caliper properly on the axis of the work, as shown in B, figure 85.



A

SETTING OUTSIDE CALIPERS ON RULE



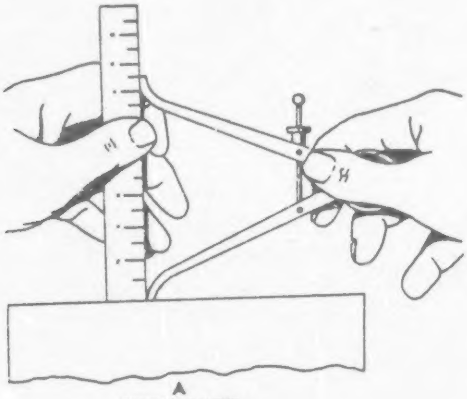
B

POSITIONING FOR CORRECT MEASUREMENT

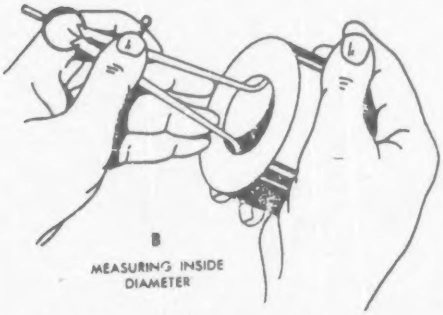
Figure 85. Using outside calipers.

OS 424, 4-P69

(2) **Inside calipers.** The inside caliper is set to a dimension by placing the end of a scale and one point of the caliper against a solid surface and adjusting the other leg to the proper graduation, as shown in A, figure 86. The spring caliper is shown being used to check the inside diameter of a bored hole in B, figure 86. Figure 87 illustrates the correct and incorrect positioning of the calipers with relation to the axis of the work. The transfer feature of the caliper is illustrated in figure 88. Note that the diameter being used is recessed and that the setting cannot be transferred to a scale directly because the legs must be collapsed to get them out of the work. The setting must be reproduced after the calipers are removed. Figure 89 shows how a micrometer can be used to transfer a dimension from an inside spring caliper.



A
SETTING CALIPER



B
MEASURING INSIDE DIAMETER

Figure 86. Setting and using inside caliper.

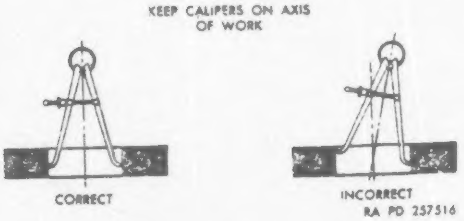


Figure 87. Positioning of inside calipers.

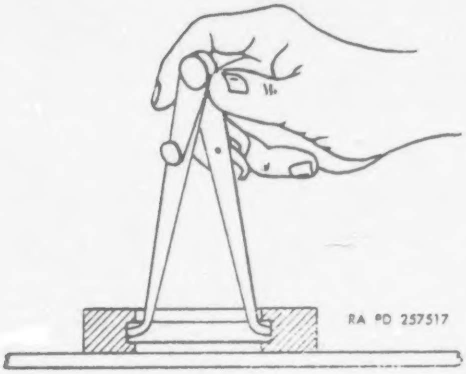


Figure 88. Using a transfer caliper to measure a recessed diameter.

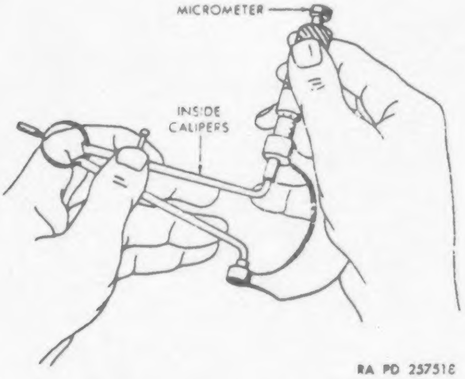


Figure 89. Transferring dimension to micrometer.

(3) Hermaphrodite calipers. The hermaphrodite caliper is adjusted and set in the same manner as the outside and inside caliper, depending on the position and use of the caliper leg, as shown in figure 90.

(4) Trammel. The trammel set is used for the same purposes as a divider or caliper, but usually for distances beyond the range of either one. Figure 91 shows the trammel with caliper point scribing an arc or establishing a distance from the edge of a machined part. The divider point and ball point are illustrated in use in figure 92. Here, the machinist is scribing distances from precise center of hole already drilled.

(5) Vernier caliper.

(a) Reading vernier caliper. The vernier caliper permits precise, accurate readings by means of the graduated steel rule and the movable jaw which carries the vernier scale. In order to see the vernier caliper, a thorough understanding of the vernier scale and how to read it are essential.

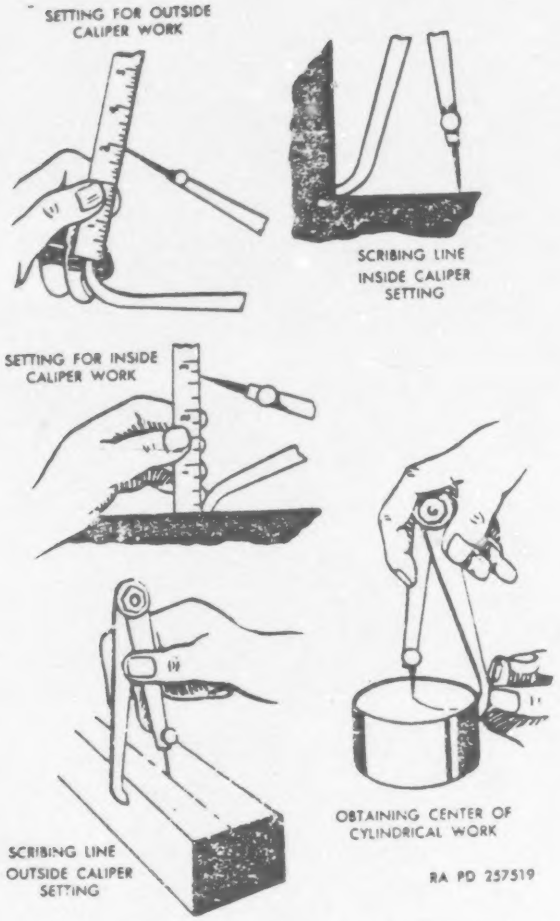

SETTING FOR OUTSIDE CALIPER WORK
SCRIBING LINE INSIDE CALIPER SETTING
SETTING FOR INSIDE CALIPER WORK
OBTAINING CENTER OF CYLINDRICAL WORK
SCRIBING LINE OUTSIDE CALIPER SETTING
RA PD 257519

Figure 90. Setting and using hermaphrodite caliper.

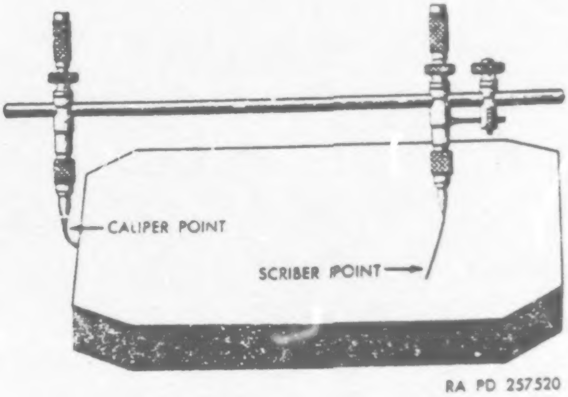

CALIPER POINT
SCRIBER POINT
RA PD 257520

Figure 91. Using trammel with caliper and scriber points.

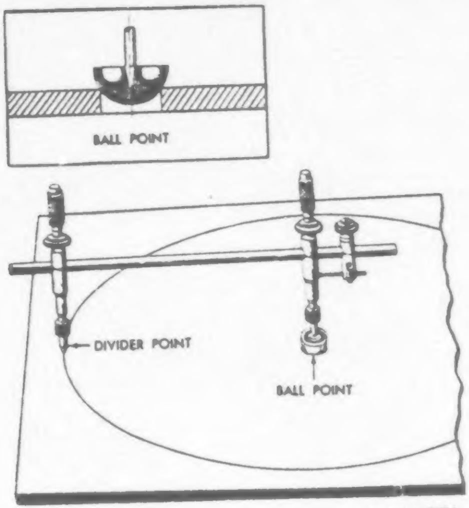


Figure 92. Using trammel with divider and ball points.

1. The steel rule of the caliper is graduated in fortieths or 0.025 of an inch. Every fourth division, representing a tenth of an inch, is numbered, as shown in the enlarged view on figure 93. The vernier scale is divided into 25 parts and numbered 0, 5, 10, 15, 20, and 25. These 25 parts are equal to and occupy the same space as 24 parts on the tule. The difference between the width of one of the 25 spaces on the vernier scale and one of the 24 spaces on the rule is 1/25 of 1/40, or 1/1000 of an inch. If the tool is set so that the 0 line on the vernier coincides with the 0 line on the rule, the line to the right of 0 on the vernier scale will differ from the line to the right of 0 on the rule by 1/1000 of an inch; the second line by 2/1000 of an inch; and so on. The difference will continue to increase 1/1000 of an inch for each division until the line 25 on the vernier scale coincides with the line 24 on the rule. To read the scales, note how many inches, tenths (or 0.100), and fortieths (or 0.025) the mark 0 on the vernier scale is from 0 mark on the rule; then note the number of divisions on the vernier scale from 0 to a line which exactly coincides with a line on the rule.

2. For example, A, figure 93, shows the 0 mark of the vernier scale coinciding with a line on the rule. In this case, the vernier scale is not necessary since there is no fractional part of a space to determine. The reading is 2.350. The 0 mark on the vernier scale, as shown in B, figure 93, coincides with a fractional part of a space on the rule. The reading is 2.35 plus a fraction of the space on the rule. In order to determine what fractional part of a whole rule division, or how many thousands are to be added to the 2.35 reading, it is necessary to find the line on the vernier scale that exactly coincides with the line on the rule. In this case the line coincides at the 18th mark. This indicates 18/25 of a whole space. Since each space on the rule equals 0.025 inch, this part of a space is equal to 0.018 inch, and the total reading is 2.35 plus 0.018, or 2.368 inches.

OS 424, 4-P73

3. Vernier scales are not necessarily 25 divisions long; they may have any number of units. For example, the ten-thousandths micrometer has a vernier scale of only ten divisions.

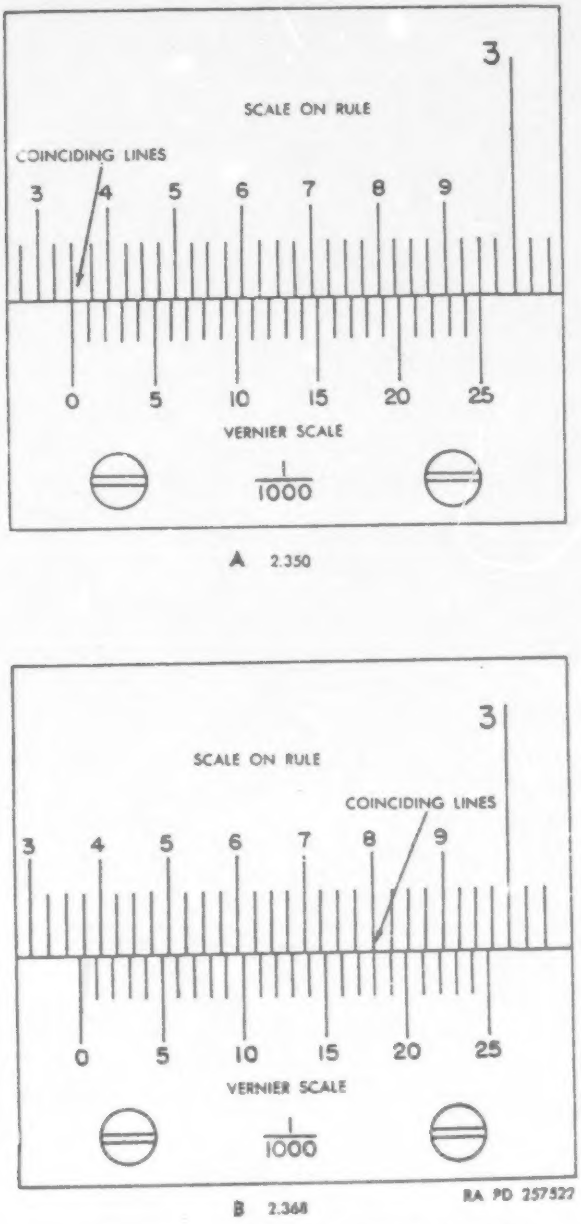
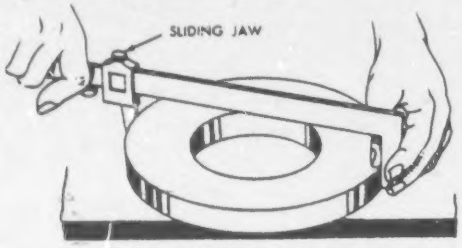
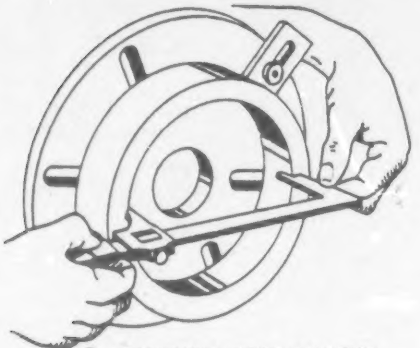

3
SCALE ON RULE
COINCIDING LINES
3 4 5 6 7 8 9
0 5 10 15 20 25
VERNIER SCALE
1/1000
A 2.350
3
SCALE ON RULE
COINCIDING LINES
3 4 5 6 7 8 9
0 5 10 15 20 25
VERNIER SCALE
1/1000
B 2.368
RA PD 257522

Figure 93. Reading a vernier scale.

(b) Applications. The vernier caliper has a wide range of measurement applications, and the shape of the measuring jaws and their position with respect to the scale makes this tool more adaptable than a micrometer. However, the vernier caliper does not have the accuracy of a micrometer. In any 1 inch of its length, a vernier caliper should be accurate within 0.001 inch. In any 12 inches, it should be accurate within 0.002 inch and increase about 0.001 for every additional 12 inches. The accuracy of measurements made with a vernier caliper is dependent on the user's ability to feel the measurement. Because the jaws are long, and because there is the possibility of some play in the adjustable jaw, especially if an excessive measuring pressure is used, it is necessary to develop an ability to handle the vernier caliper. This touch may be acquired by measuring such known standards as gage blocks and plug gages. Applications of the vernier calipers are shown in figure 94. In A, a machinist is checking the outside diameter of a part. One hand holds the stationary jaw to locate it, while the other hand operates the adjusting nut and moves the sliding jaw to the work. The same procedure is used in B in checking the inside dimension.



A—MEASURING OUTSIDE DIAMETER



B—MEASURING INSIDE DIAMETER

Figure 94. Using a vernier caliper.

(6) Slide caliper. All slide calipers are equipped with a locking or clamping device, which makes it possible to hold the jaws in any desired position. Outside dimensions are taken off the graduated scale line that matches the inner edge of the fixed jaw. Inside dimensions are read opposite the mark or graduation line on the fixed jaw.

c. Care of calipers.

(1) The information in 24c above on the care of the divider is also applicable to the care of calipers and trammels. Specific information on the care of vernier calipers is in (2) below.

(2) The accuracy of the vernier caliper depends on the condition of fit of the sliding jaw, and on the wear and distortion in the measuring surfaces. The fit of the sliding jaw should be such that it can be moved easily and still not have any play. It may be adjusted by removing the gib in the sliding jaw assembly and bending it. The function of the gib is to hold the adjustable jaw against the inside surface of the blade with just the right pressure to give it the proper friction. Wear on the jaws of the vernier caliper is mostly at the tips where most measurements are made. A certain amount of this wear may be taken up by adjusting the vernier scale itself. This scale is mounted with screws in elongated holes which permit it to be adjusted slightly to compensate for wear and distortion. When the error exceeds 0.0002 inch, either in parallelism or flatness, the caliper should be returned to the manufacturer for reconditioning. Wear on the jaws can best be checked by visual means and by measuring rolls or rings of known dimensions.

26. MICROMETERS. Micrometers are used for measurements requiring precise accuracy. They are more reliable and more accurate than the calipers discussed in the preceding section.

a. Types of micrometers. Micrometers are made in various shapes and sizes, depending upon the purpose for which they are to be used. They all have a precision screw adjustment offering great measuring accuracy.

(1) Micrometer caliper.

(a) The micrometer caliper (fig 95) is the most common type. It has a range of 0 to 1 inch and is graduated to read in thousands of an inch or in units of the Metric system, from 0 to 25 millimeters by hundredths of a millimeter.

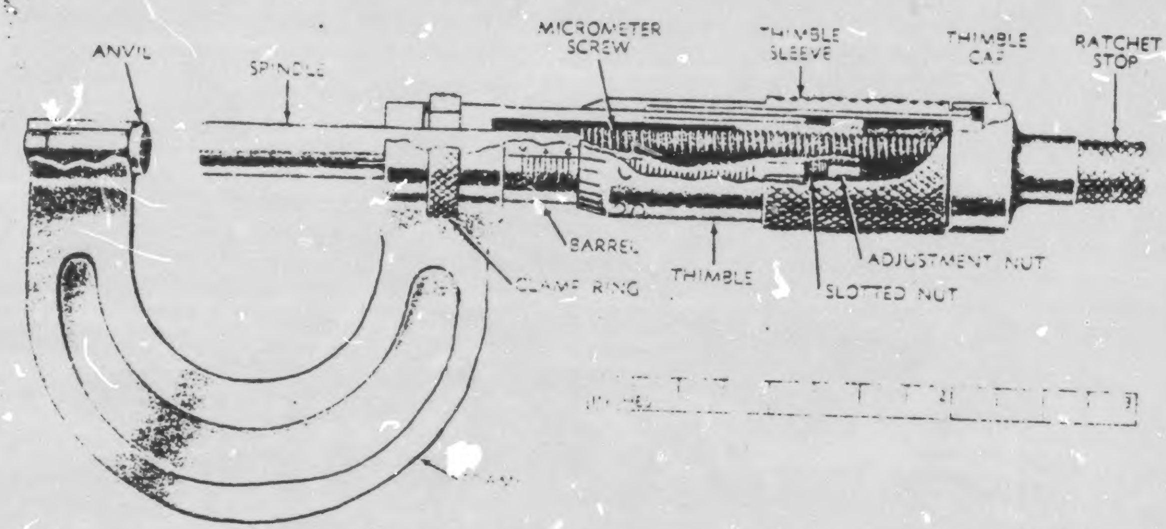


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Figure 95. Micrometer caliper, cutaway view.

(b) The frame can be smaller to the extent that the range of the caliper is only 0 to 1/2 inch or 0 to 13 millimeters, or it can be larger so that the range is 23 to 24 inches. The head has a constant range of 0 to 1 inch. The shape of the frame may be varied to adapt it to the physical requirements of some types of work. For example:

1. The frame back of the anvil may be cut away to allow the anvil to be placed in a narrow slot.

2. The frame may have a deep throat to permit it to reach into center sections of a sheet (sheet metal or paper gage).

3. The frame may be in the form of a base so that the gage can be used as a bench micrometer.

4. The frame may have a wooden handle and may be of extra-heavy construction for use in a steel mill for gaging hot sheet metal.

(c) The spindle and anvil may vary in design to accommodate special physical requirements. For example:

1. The spindle and anvil may be chamfered so that the gage can slide on and off the work easily, as when gaging hot metal.

2. The ball-shaped anvil is convenient in measuring the thickness of a pipe section of small diameter.

3. The V-shaped anvil is necessary on the screw thread micrometer caliper to mesh properly with the screw thread. The spindle of the screw thread micrometer is cone-shaped. This micrometer measures the pitch diameter.

4. The interchangeable anvils of various lengths make it possible to reduce the range of the caliper. A micrometer having a range from 5 to 6 inches can be changed to one having a 4 to 5, or 3 to 4-inch range by inserting a special anvil of the proper length.

(2) Inside micrometers. Inside micrometers are used to measure inside dimensions. The minimum dimension that can be checked is determined by the length of the unit with its shortest anvil in place and the screw set up to zero. It consists of an ordinary micrometer head, except that the outer end of the sleeve carries a contact point attached to a measuring rod. The average inside micrometer set (fig 96) has a range that extends from 2 to 10 inches. The various steps in covering this range are obtained by means of extension rods. The micrometer set may also contain a collar for splitting the inch step between two rods. The collar, which is 1/2 inch long, extends the rod another half inch so that the range of each step can be made to overlap the next. The range of the micrometer screw itself is very short when compared to its measuring range. The smallest models have a 1/4-inch screw, the average have a 1/2-inch screw, and the largest inside micrometers have only a 1-inch screw.

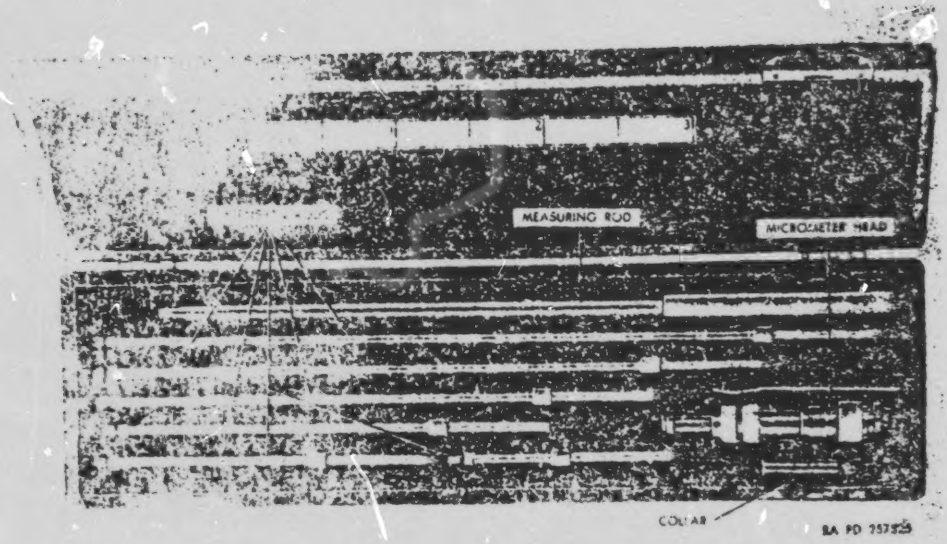


Figure 96. Inside micrometer set.

b. Mechanics of micrometers.

(1) Design. The micrometer (fig 95) makes use of the relation of the circular movement of a screw to its axial movement. The amount of axial movement of a screw per revolution depends on the thread, and is known as the lead. If a circular nut on a screw has its circumference divided into 25 equal spaces, and if the nut advances axially 1/40 inch for each revolution, then if it is turned one division, or 1/25 of a revolution, it will move axially 1/25 x 1/40, or 1/1000 of an inch. In the micrometer the nut is stationary and the screw moves forward axially a distance proportional to the amount it is turned. The screw on a micrometer has 40 threads to the inch, and the thimble has its circumference divided into 25 parts, so 1 division on the thimble represents an advancement of 1/1000 of an inch axially.

(2) Construction.

(a) The steel frame is U-shaped, one end of which holds the stationary anvil. The stationary anvil is a hardened button either pressed or screwed into the frame.

(b) The steel spindle is actually the unthreaded part of the screw. It is the spindle that advances or retracts to open or close the open side of the U-frame. The spindle bearing is a plain bearing and a part of the frame.

(c) The hollow barrel extends from this bearing, and on the side of the barrel is the micrometer scale, which is graduated in tenths of an inch, which are in turn divided into subdivisions of 0.025 inch. The end of the barrel supports the nut which engages the screw. This nut is slotted and its outer surface has a taper thread and a nut which makes it possible to adjust the diameter of the slotted nut within limits to compensate for wear.

(d) The thimble is attached to the screw and is a sleeve that fits over the barrel. The front edge of the thimble carries a scale broken down into 25 parts. This scale indicates parts of a revolution, where the scale on the barrel indicates the number of revolutions. The thimble is connected to the screw through a sleeve that permits it to be slipped in relation to the screw for the purpose of adjustment. The inner sleeve is sweated to the screw. The outer sleeve is clamped to the inner one by the thimble cap. Loosening the cap makes it possible to slip one in relation to the other.

(e) On top of the thimble cap there may be a ratchet. This device consists of an overriding clutch held together by a spring in such a way that when the spindle is brought up against the work, the clutch will slip when the correct measuring pressure is reached. The purpose of the ratchet is to eliminate any difference in personal touch and so reduce the possibility of error due to a difference in measuring pressure. Not all micrometers have ratchets.

(f) The clamp ring or locknut is located in the center of the spindle bearing on those micrometers equipped with it. This clamping makes it possible to lock the spindle in any position to preserve a setting.

c. Use of micrometers.

(1) Reading standard micrometer. Reading a micrometer is only a matter of reading the micrometer scale or counting the revolutions of the thimble and adding to this any fraction of a revolution. The micrometer screw has 40 threads per inch. This means that one complete and exact revolution of the micrometer screw moves the spindle away from or towards the anvil exactly 0.025 inch. The lines on the barrel (fig 97) conform to the pitch of the micrometer screw, each line indicating 0.025 inch, and each fourth line being numbered 1, 2, 3, and so forth. The beveled edge of the thimble is graduated into 25 parts, each line indicating 0.001 inch, 1/25 of the 0.025 inch covered by one complete and exact revolution of the thimble. Every fifth line on the thimble is numbered to read a measurement in thousandths of an inch. Read the measurement shown in figure 97 as indicated in (a) through (d) below.

(a) Record highest figure visible on barrel . . . . 2 = 0.200 in

(b) Number of lines visible between the No 2 and thimble edge . . . . 1 = 0.025 in

(c) The line on the thimble that coincides with or has passed the revolution or long line in the barrel. . . . . . 16 = 0.016 in

(d) Measurement reading. . . . TOTAL = 0.241 in

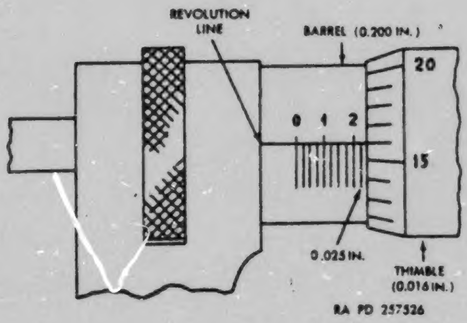


Figure 97. Reading standard micrometer scale.

(2) Reading metric micrometer. The same principle is applied in reading the metric graduated micrometer, but the following changes in graduations should be noted to avoid confusion:

(a) The pitch of the micrometer screw is 0.5mm. One revolution of the spindle advances or withdraws the screw a distance equal to 0.5mm.

(b) The barrel is graduated in millimeters, from 0 to 25; it takes two revolutions of the spindle to move 1mm.

(c) The thimble is graduated in 50 divisions with every fifth line being numbered.

(d) Rotating the thimble from one graduation to the next moves the spindle 1/50 of 0.5mm, or 1/100mm. Two graduations equal 2/100mm, and so forth.

(3) Adjusting micrometer caliper to work.

(a) A, figure 98, shows the proper way to hold a micrometer caliper in checking a small part. Hold the part in one hand. Hold the micrometer in the other hand so that the thimble rests between the thumb and the forefinger. The third finger is then in a position to hold the frame against the palm of the hand. The frame is supported in this manner and makes it easy to guide the work over the anvil. The thumb and forefinger are in position to turn the thimble either directly or through the ratchet and bring the spindle over against the work.

(b) On larger work, it is necessary to have the work stationary and positioned to permit access to the micrometer. The proper method of holding a micrometer when checking a part too large to be held in one hand is shown in B, figure 98. The frame is held by one hand to position it and to locate it square to the measured surface. The other hand operates the thimble either directly or through the ratchet. A large flat part should be checked in several places to determine the amount of variation.

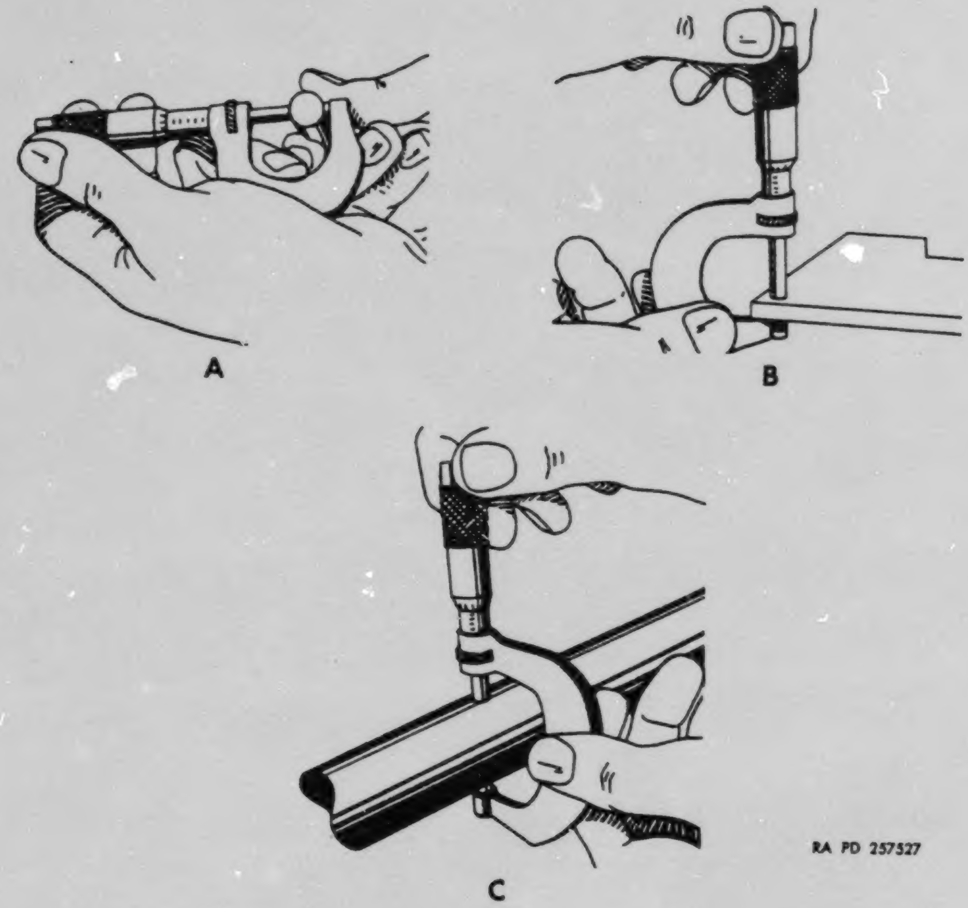


Figure 98. Using outside micrometer.

(c) To gage a shaft as shown in C, figure 98, the frame is held by one hand while the thimble is operated by the other. In gaging a cylindrical part with a micrometer it is necessary to "feel" the setting to be sure that the spindle is on the diameter, and also to check the diameter in several places to determine the amount of out-of-roundness.

(d) For measuring very large diameters, micrometer calipers are made in various sizes up to 168 inches. Figure 99 shows a pulley being checked with a micrometer whose range has been reduced by a special anvil which has been screwed into the frame. A set of different length anvils permits the use of this micrometer over a wide range of sizes; yet the spindle only moves 1 inch. This micrometer has been lightened in weight by the I-section construction and by boring holes in the frame.

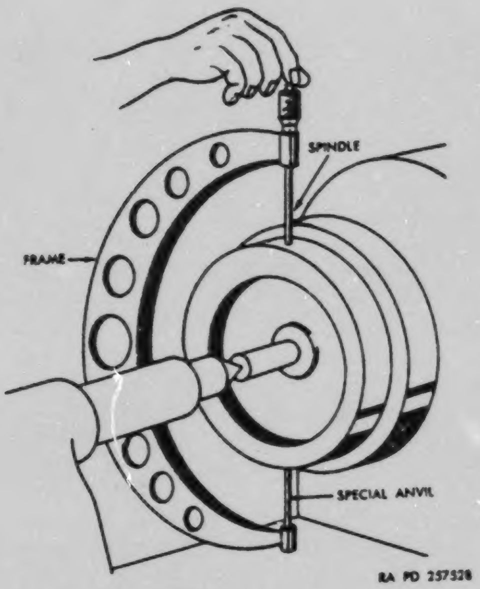


Figure 99. Checking diameter of pulley.

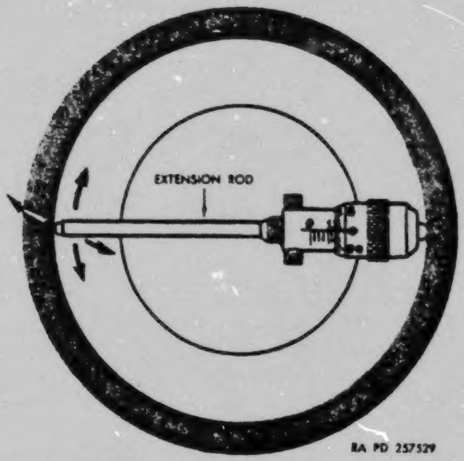
(4) Using inside micrometer. The normal procedure in using an inside micrometer is to set it across a diameter or between the inside surfaces, remove it, and then read the dimension. For this reason, the thimble on an inside micrometer is much stiffer than on a micrometer caliper—it holds the dimension well. It is good practice to verify the reading of an inside micrometer by measuring it with a micrometer caliper.

(a) Figure 100 shows an inside micrometer with extension rod being used to check the diameter of a bored hole. Note the arrows which indicate the direction the operator is feeling for the largest dimension horizontally and the smallest dimension vertically. Inside micrometers have spherical contact points which require more practice to "feel" the full diametral measurement. One contact point is generally held in a fixed position and the other rocked in different directions to be sure the tool is spanning the true diameter of a hole or the correct width of a slot.

(b) For probing a deep hole or in a restricted place, a handle attachment may be used. The handle clamps on to the body of the micrometer.

(5) Transferring measurements from inside caliper or inside micrometer to micrometer caliper.

(a) After setting the inside caliper or inside micrometer to the work, hold the micrometer caliper in one hand and the inside tool in the other hand.



RA PD 257529

Figure 100. Using inside micrometer with extension rod.

(b) Turn the thimble of the micrometer caliper with the thumb and forefinger until you feel the inside tool legs lightly contact the anvil and spindle of the micrometer caliper.

(c) Hold the tips of the inside tool legs parallel to the axis of the micrometer caliper spindle.

(d) The micrometer caliper will be accurately set when the inside tool will just pass between the anvil and spindle by its own weight.

d. Care of micrometers. To maintain a micrometer in good condition and to preserve the accuracy of its measurements, observe the following rules of good practice and adjusting procedures:

(1) Never store a micrometer with its anvil and spindle closed. Flat surfaces wrung together for any length of time tend to corrode. Leave a small gap between the anvil and spindle when storing.

(2) Oil the micrometer in only one place—the micrometer screw, and only with a very light oil. If storing for long periods of time, cover the micrometer with a light film of oil and wrap it in oiled paper.

(3) Never roll the thimble along the hand or arm. Likewise, holding the thimble and twirling the frame to open or close the micrometer will cause excessive wear on the screw.

(4) Before using a micrometer, wipe it off and pull a piece of paper between the anvil and end of the spindle.

(5) The micrometer should operate freely with no play in its travel. If a micrometer has play, or if it binds, it should be returned to the manufacturer for reconditioning. This condition is caused by abuse or uneven wear.

(6) Check the micrometer screw periodically with a precision gage block in at least four places other than zero to verify its accuracy. Simply measure a selected group of blocks ranging from 0 to 1 inch.

(7) Clean micrometer mechanism whenever it becomes gummy, contains abrasive grit, or whenever it is to be adjusted. Use an approved cleaning agent.

(8) When the faces of the spindle and anvil become worn and they are no longer flat and parallel to each other, the error should not exceed 0.0002 inch on a micrometer which is graduated to control measurements to a limit of 0.001 inch and should not exceed 0.00005 inch on a micrometer which is graduated to control measurements to a limit of 0.0001 inch. Measuring a ball at several points over the surface of the anvils will show up any error in parallelism. Parallelism can be tested by means of two balls mounted in an aluminum holder. If the anvils are in error more than the allowable maximum, the micrometer should be returned to the manfuacturer for repair.

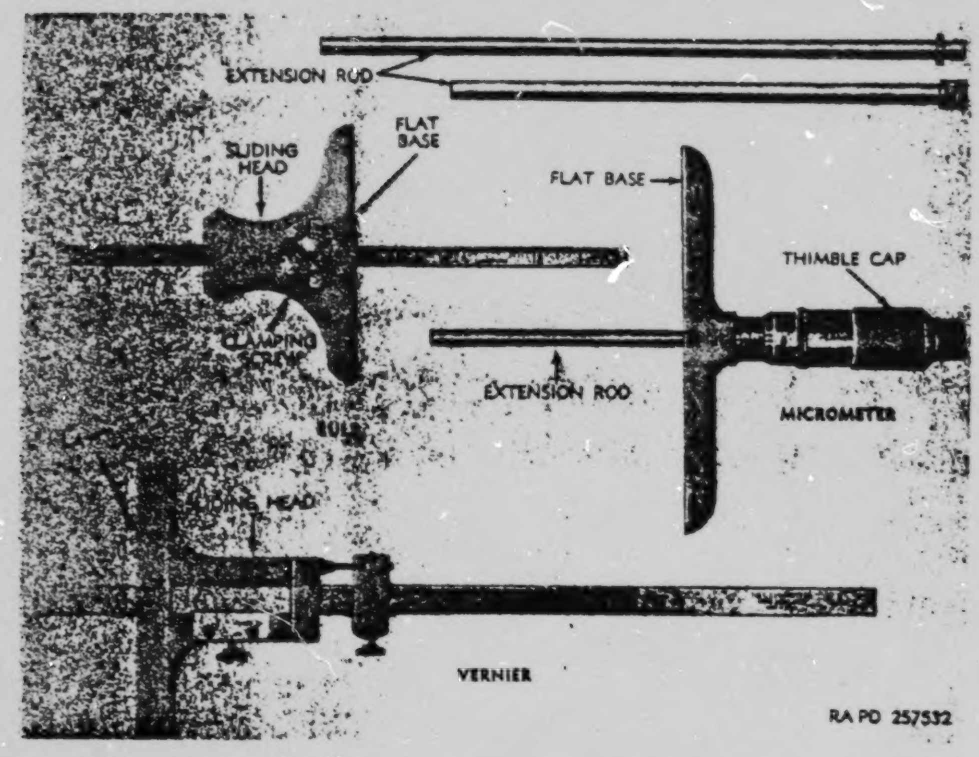
(9) In adjusting a micrometer to read correctly, the thimble is not set to 0 when the anvil is in contact with the spindle, but is set at some dimension to distribute the error. For example, if a micrometer screw had an accumulating error of 0.0003 inch in the length of its travel, and it were set correctly at 0, it would be off 0.0003 at 1 inch. However, if the micrometer were set correctly in the center of its travel, it would be 0.00015 under at 0 and 0.00015 over at 1 inch, which is a much better condition. Because a micrometer does not return exactly to 0 when the anvil and spindle contact, it does not mean that it is not adjusted properly. Turn the friction sleeve with a small spanner wrench to compensate for minor wear on the anvil and spindle or on the screw.

27. **GAGES.** There are a number of tools that are called gages and may be used for measuring or testing and setting distances. Some of the gages that will be discussed here will also be useful for layout work as well as for measuring.

a. Depth gages (fig 101). A depth gage is an instrument for measuring the depth of holes, slots, counterbores, recesses, and the distance from a surface to some recessed part. The most commonly used depth gages are the rule depth gage, micrometer depth gage, and vernier depth gage.

(1) The rule depth gage is a graduated rule with a sliding head designed to bridge a hole or slot, and to hold the rule perpendicular to the surface on which the measurement is taken. This type has a measuring range of 0 to 5 inches. The sliding head has a clamping screw so that it may be clamped in any position. The sliding head has a flat base which is perpendicular to the axis of the rule and ranges in size from 2 to 2-5/8 inches in width and from 1/8 to 1/4 inch in thickness.

(2) The micrometer depth gage consists of a flat base attached to the barrel (sleeve) of a micrometer head. These gages have a range from 0 to 9 inches, depending on the length of the extension rod used. The hollow micrometer screw (the threads on which the thimble rotates) itself has a range of either 1/2 or 1 inch. Some are provided with a ratchet stop. The flat base ranges in size from 2 to 6 inches. Several extension rods are normally supplied with this type of gage.



RA PD 257532

Figure 101. Types of depth gages.

(3) The vernier depth gage consists of a graduated scale, either 6 or 12 inches long, and a sliding head similar to the one on the vernier caliper. The sliding head is especially designed to bridge holes and slots. The vernier depth gage has the range of the rule depth gage and not quite the accuracy of a micrometer depth gage. It cannot enter holes less than 1/4 inch in diameter, whereas a micrometer depth gage will enter a 3/32-inch hole. However, it will enter a 1/32-inch slot, whereas a micrometer gage will not. The vernier scale is adjustable and may be adjusted to compensate for wear.

b. Surface gage. A surface gage is a measuring tool generally used to transfer measurements to work by scribing a line and to indicate the accuracy or parallelism of surfaces.

(1) The surface gage (fig 102) consists of a base with an adjustable spindle to which may be clamped a scriber or an indicator. Surface gages are made in several sizes and are classified by the length of the spindle, the smallest spindle being 4 inches long, the average 9 or 12 inches long, and the largest 18 inches. The scriber is fastened to the spindle with a clamp. The bottom and the front end of the base of the surface gage have deep V-grooves cut in them, which allow the gage to measure from a cylindrical surface.

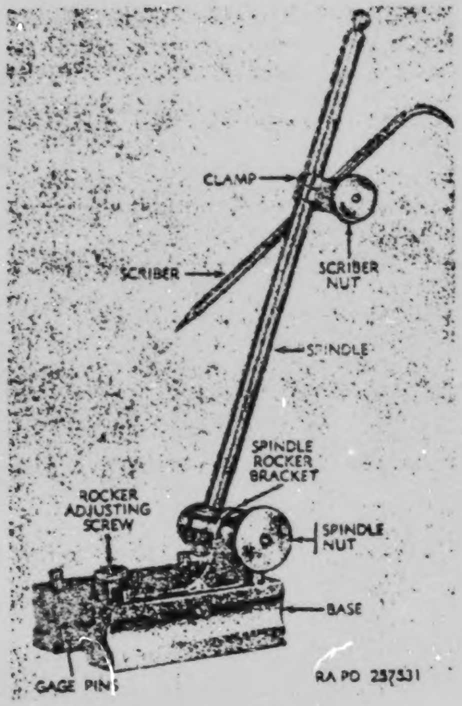


Figure 102. Surface gage.

(2) The spindle of a surface gage may be adjusted to any position with respect to the base and tightened in place with the spindle nut. The rocker adjusting screw provides for the finer adjustment of the spindle by pivoting the spindle rocker bracket. The scriber can be positioned at any height and in any desired direction on the spindle by tightening the scriber nut. The scriber may also be mounted directly in the spindle nut mounting, in place of the spindle, and used where the working space is limited and the height of the work is within range of the scriber.

c. Surface plate.

(1) A surface plate provides a true, smooth, plane surface. It is a flat-topped steel or cast iron plate that is heavily ribbed and reinforced on the under side (fig 103). It is often used in conjunction with a surface gage as a level base on which the gage and part to be measured are placed to obtain accurate measurements.

(2) The surface plate can also be used for testing parts that must have flat surfaces. Before using the plate for testing smear a thin film of Prussian blue, or some other color pigment, on its surface; then rub the flat surface to be tested over the plate and the color pigment will stick to the high spots.

(3) The surface plate should be covered when not in use to prevent scratching, nicking, and denting. It must be handled carefully to prevent warping (twisting). Never use the surface plate as an anvil or workbench—except for precision layout work (marking and measuring).

28.25.3

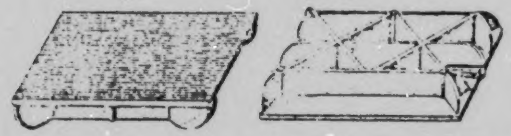
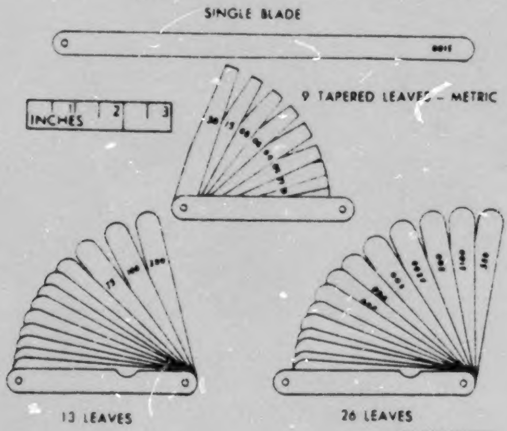

44.28

Figure 103. Surface plate.

d. Thickness (feeler) gage.

(1) Thickness (feeler) gages are fixed in leaf form to permit the checking and measuring of small openings such as contact points, narrow slots, and so forth. They are widely used to check the flatness of parts in straightening and grinding operations and in squaring objects with a try square.

(2) Thickness gages are made in many shapes and sizes; usually 2 to 26 blades are grouped into one tool and graduated in thousandths of an inch (fig 104). Most thickness gage blades are straight, but some are bent at the end at 45° and 90° angles. Some thickness gages are grouped so that there are several short and several long blades together. Thickness gages are also available in single blades and in strip form for specific measurements. For convenience, groups of thickness blades are equipped with a locking screw in the case that locks the blade to be used in the extended position.



RA PD 257555

Figure 104. Thickness (feeler) gages.

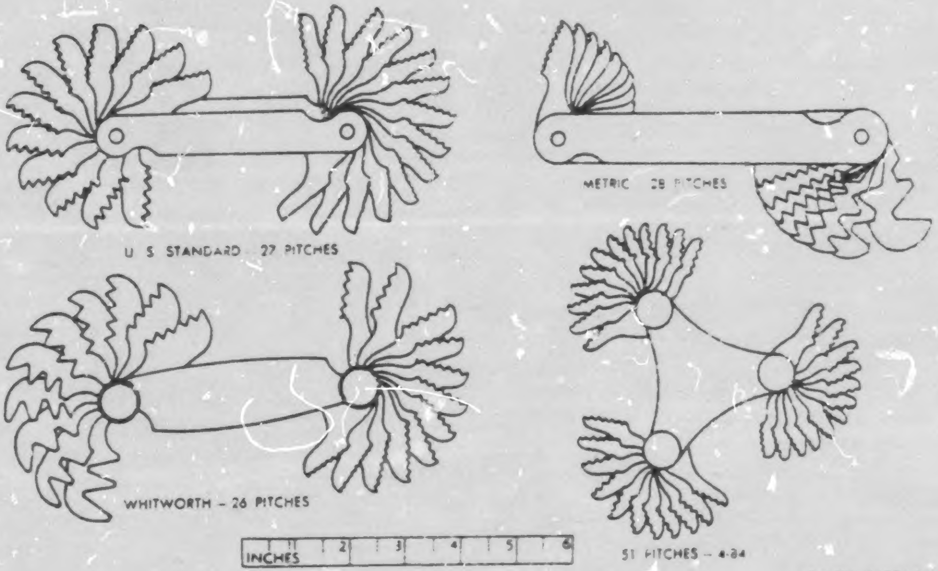
e. Thread gage.

(1) Thread gages (screw-pitch gages) are used to determine the pitch and the number of threads per inch (fig 105). They consist of thin leaves whose edges are toothed to correspond to standard thread sections.

(2) To measure the pitch of a thread, compare it with the standards of the gage holding a gage leaf to the thread being gaged until you find an exact fit. If possible, look at the fit toward a source of light, since a difference of one thread per inch, in the finer threads, is not easily detected.

(3) The number of threads per inch is indicated by the numerical value on the blade which is found to fit the threads. Using this value as a basis, correct sizes of nuts, bolts, tap cutters, and die cutters are selected for use on the threads.

(4) If the number of threads per inch on a nut equal the number of threads per inch on a bolt, the nut can be successfully applied without danger of stripping the threads on either.



RA PD 257557

Figure 105. Screw pitch gages.

f. Wire gage. The wire gage (fig 106) is used for gaging metal wire, and a similar gage is used to check the size of hot and cold rolled steel, sheet and plate iron, and music wire. The wire gage is circular in shape with cutouts in the outer perimeter. Each cutout gage is different size wire from 0 to 36 of the English Standard Wire Gage. A different gage is used for American Standard wire, and still another for US Standard sheet and plate iron and steel.

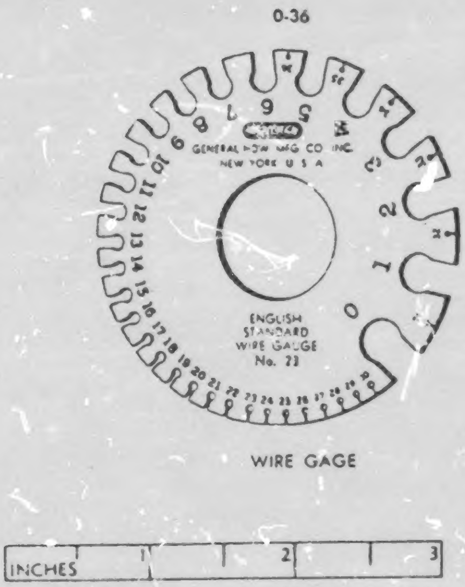

0-36
GENERAL HDW MFG CO INC
NEW YORK U S A
ENGLISH
STANDARD
WIRE GAUGE
No. 23
WIRE GAGE
INCHES
1
2
3

Figure 106. English Standard Wire Gage.

g. Telescoping gage.

(1) Telescoping gages are used for measuring the inside size of slots or holes up to 6 inches in width or diameter. They are T-shaped tools in which the shaft of the T is used as a handle and the crossarm for measuring (fig 107). The crossarms telescope into each other and are held out by a light spring. To use the gage the arms are compressed, placed in the hole to be measured, and allowed to expand. A twist of the locknut on top of the handle locks the arms. The tool may then be withdrawn and the distance across the arms measured.

(2) These tools are commonly furnished in sets, the smallest gage for measuring distances from 5/16 to 1/2 inch, and the largest for distances from 3-1/2 to 6 inches.

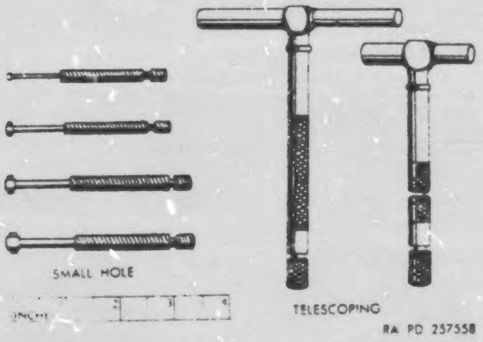

SMALL HOLE
INCHES
TELESCOPING
RA PD 257558

Figure 107. Small hole and telescoping gages.

h. Small hole gage.

(1) For measuring smaller slots or holes than the telescoping gages will measure, small hole gages can be used. These gages come in sets of four or more and will measure distances of approximately 1/8 to 1/2 inch.

(2) The small hole gage (fig 107) consists of a small, split, ball-shaped member mounted on the end of a handle. The ball is expanded by turning a knurled knob on the handle until the proper feel is obtained, and then the size of the ball-shaped member on the end of the gage can be measured with an outside micrometer caliper. On some types of small hole gages, the ball is flattened at the bottom near the centerline to permit use in shallow holes and recesses.

i. Center gage. The center gage (fig 108) is graduated in 14ths, 20ths, 24ths, and 32ds of an inch. The back of the center gage has a table giving the double depth of thread in thousandths of an inch for each pitch. This information is useful in determining the size of tap drills. Sixty-degree angles in the shape of the gage are used for checking Unified and American threads as well as for older American National or United States standard threads and for checking thread cutting tools.

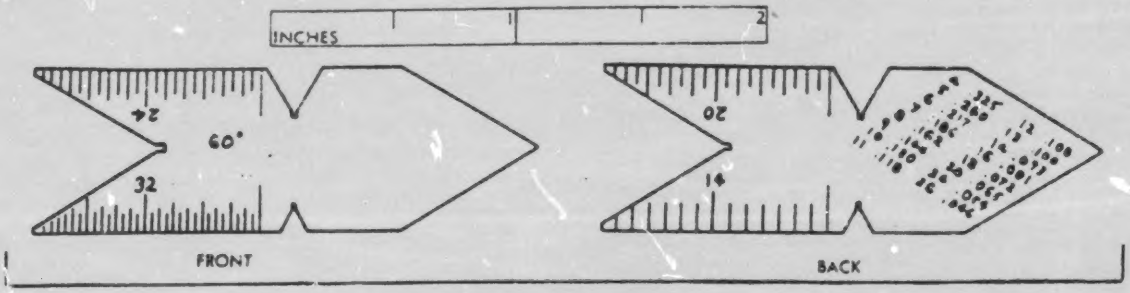


Figure 108. Center gage

j. Marking gages.

(1) A marking gage is used to mark off guidelines parallel to an edge, end, or surface of a piece of wood or metal. It has a sharp spur or pin that does the marking.

(2) Marking gages (fig 109) are made of wood or steel. They consist of a graduated beam about 8 inches long, on which a head slides. The head can be fastened at any point on the beam by means of a thumbscrew. The thumbscrew presses a brass shoe tightly against the beam and locks it firmly in position. A steel pin or spur marks the wood. The spur projects from the beam about 1/4 inch.

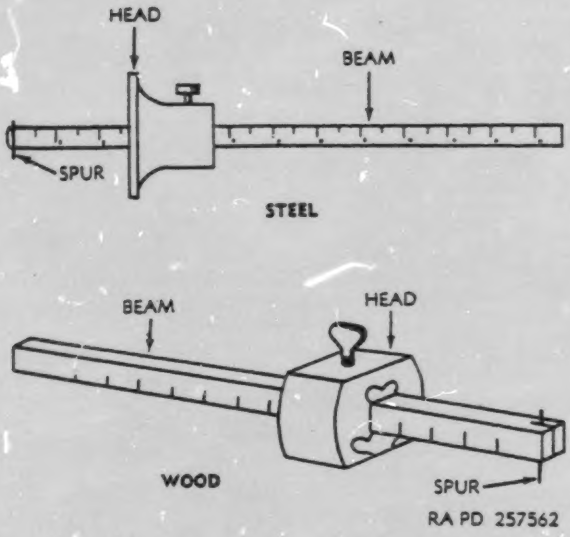


Figure 109. Marking gages.

k. Care of gages. Always coat metal parts of all gages with a light film of oil when not in use to prevent rust. Store gages in separate containers. Do not pile gages on each other. Always return blades of leaf-type gages to the case after use. Keep graduations and markings on all gages clean and legible. Do not drop any gage—minute scratches or nicks will result in inaccurate measurements.

SECTION III. BASIC METALWORKING MACHINES

28. INTRODUCTION. The mission requirements of maintenance organizations are so varied that it is essential for them to be equipped with tools and machines that will provide them with the capability of coping with different maintenance situations. Most maintenance organization's work, to some extent, involves processing metals of some type and, therefore, requires tools or machines that are rugged and yet may be sensitive due to the close tolerances expected. The basic metalworking machines (grinders, drill presses, hand drills, and hacksawing machine) given in the paragraphs that follow will be discussed as to type, use, and care.

a. Bench grinder. A bench grinder (fig 110) is usually an electric motor mounted on a suitable base and having the rotor shaft extended from each side, with a grinding wheel mounted on each end for sharpening tool bits, planer tools, boring tools, drills, etc. It is usually fitted with both medium and fine grain abrasive wheels; the medium wheel is satisfactory for rough grinding where a considerable quantity of metal has to be removed, or where a smooth finish is not important. For sharpening tools or grinding to close limits of size, the fine wheel should be used as it removes metal slower, gives the work a smooth finish, and does not generate enough heat to anneal cutting edges. When a deep cut is to be taken on work or a considerable quantity of metal removed, it is often practical to grind with the medium wheel first and finish up with the fine wheel. The wheels are removable, and most bench grinders are so made that wire brushes, polishing wheels, or a buffing wheel can be substituted for them. Two other types of grinding machines are shown in figures 111 and 112.

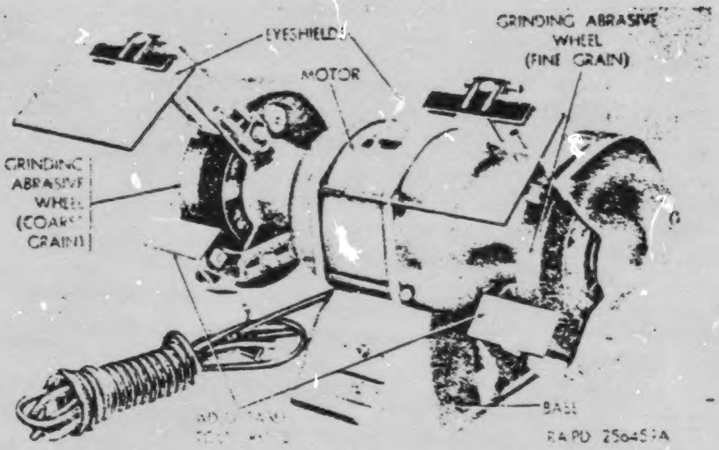

EYESHIELDS
MOTOR
GRINDING ABRASIVE WHEEL (FINE GRAIN)
GRINDING ABRASIVE WHEEL (COARSE GRAIN)
BASE
RA PD 256459A

Figure 110. Bench-type utility grinding machine.

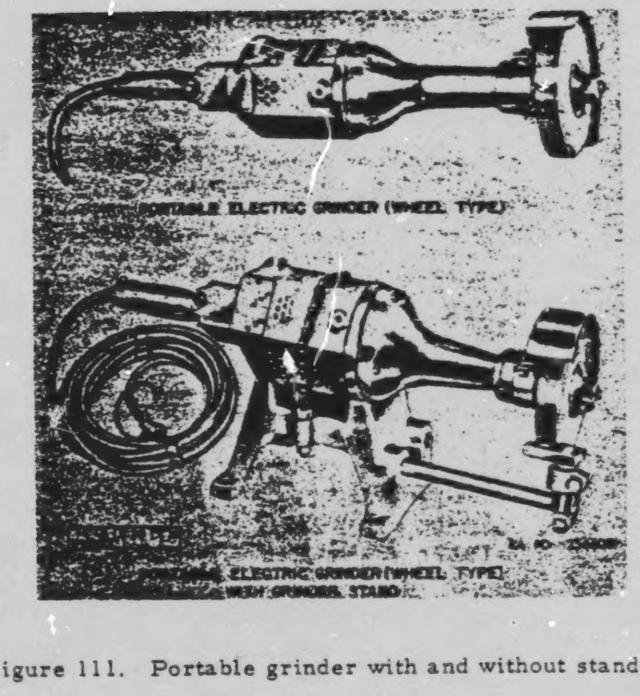

PORTABLE ELECTRIC GRINDER (WHEEL TYPE)
PORTABLE ELECTRIC GRINDER (WHEEL TYPE) WITH GRINDER STAND

Figure 111. Portable grinder with and without stand.

(1) Use and care of bench grinders. Before using the bench grinder the work should be held firmly at the correct angle on the rests provided and fed into the wheel with enough pressure to remove the desired amount of metal without generating too much heat. The rests are removable, if necessary, for grinding odd-shaped or large work. As a rule, it is not advisable to grind work requiring heavy pressure on the side of the wheel, as the pressure may crack the wheel. As abrasive wheels become worn, their surface speed decreases and reduces their cutting efficiency. When a wheel becomes worn in this manner, it should be discarded and a new one installed on the grinder. The bearings and motor of the tool are provided with cups for lubrication, as directed by the manufacturer of the tool.

(2) Safety precautions. Before using grinders, make sure that the wheels are firmly held on the spindles by the flange nuts and that the work rests are tight. Wear goggles, even if eyeshields are attached to the grinder, and bear in mind that it is unsafe even to use grinder without wheel guards. Use the rest provided on the grinder frames to support the work when grinding. Proper tool rest adjustment is 1/16" to 1/8" from the wheel. Hold the tools that are being shaped properly so that they will not catch in the abrasive wheel; otherwise, they will slip and injure the operator or wear the wheel excessively. Never use a cracked wheel. Before installing a wheel, tap it lightly with a mallet. A ringing sound indicates that the wheel is satisfactory; a dull sound indicates that the wheel may be cracked.

b. Portable electric drills. The portable electric drills (fig 113) discussed in the following paragraphs have the following characteristics in common. Each drill is powered by a universal (AC/DC) electric motor built into the drill case. The motor drives the chuck spindle and chuck through an arrangement of gears that reduces the spindle speed from that of the motor shaft and increases the rotational power. Each portable electric drill has a bottom device by which the trigger switch can be locked in the operating position when required, although under normal operation the drill stops when the switch is released.

(1) Types and use.

(a) The 1/4-inch capacity portable electric drill is a heavy-duty drill capable of drilling 1/4-inch holes in steel or 1/2-inch holes in hardwood. The drill is equipped with a geared drill chuck that will mount any straight shank twist drill or similar tool having a shank diameter of 1/4 inch or less. The chuck spindle rotates freely at a speed of 1,900 revolutions per minute, although under full load the speed will be reduced to 1,000 to 1,200 revolutions per minute. The electric drill may have a spade-type or pistol-grip handle with a trigger switch so that the drill can be supported and operated by one hand. A vertical stand may be supplied to convert the drill to a drilling machine.

(b) The 1/2-inch capacity portable electric drill is a heavy-duty drill with geared chuck in which straight-shank twist drills or similar shanked tools 1/2 inch in diameter or smaller can be mounted. This drill is driven by a universal-type (AC/DC) electric motor and has a rated capacity of 1/2-inch holes in steel plate and 1-inch holes in hardwood. The drill is geared to rotate the chuck spindle at 550 revolutions per minute without a load and at 360 revolutions per minute with full load. Three handles are present on this drill: the rear handle, the switch handle, and the pipe handle. The rear handle and switch handle are extensions of the drill housing and are not removable, but the pipe handle screws into a socket opposite the switch handle and can be removed and replaced by a stand if desired. The stand for this drill consists of a section of pipe with a flange on the end by which the drill can be bolted to a surface.

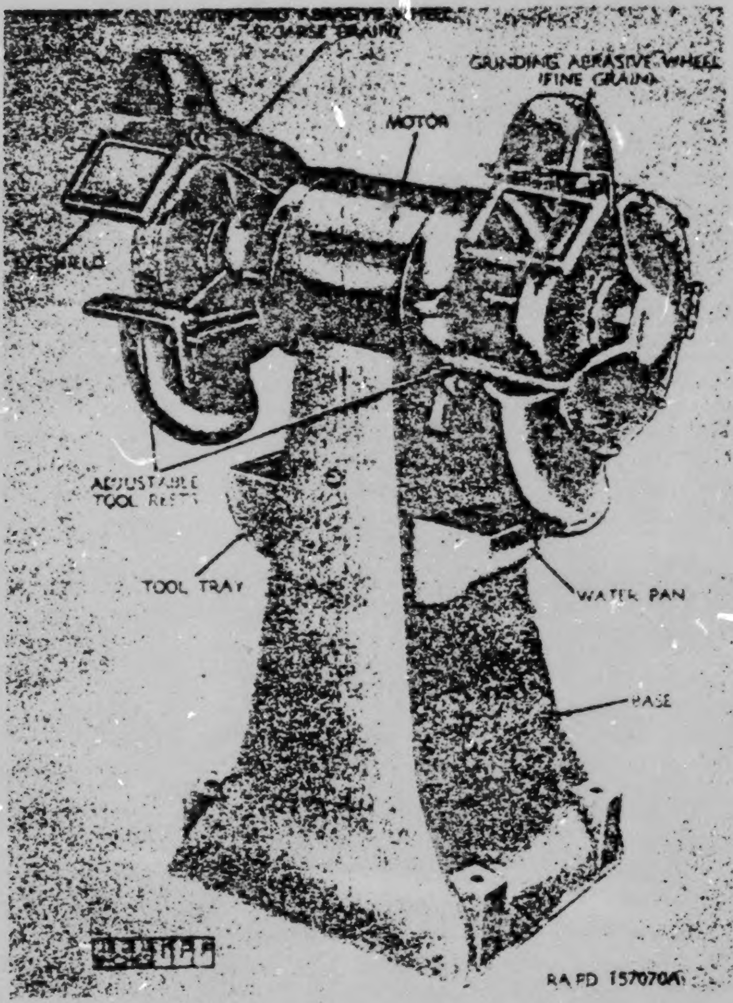

(COARSE GRAIN)
GRINDING ABRASIVE WHEEL (FINE GRAIN)
MOTOR
EYESHIELD
ADJUSTABLE TOOL RESTS
TOOL TRAY
WATER PAN
BASE
RA PD 157070A

Figure 112. Floor-mounted utility grinding machine.

(c) The 1-inch capacity taper socket portable electric drill is a larger and heavier version of the two drills previously described, being capable of drilling a hole 1 inch in diameter in steel. Instead of mounting drills in a geared drill chuck, this portable electric drill has a No 2 or No 3 taper socket for chucking twist drills and similar tools having taper shanks with tangs. This socket is similar to the drilling machine spindle that requires a drill drift for removing drills. Drill sockets, drill sleeves, and drill chucks can be mounted to the taper socket of this drill to permit chucking of larger or smaller taper-shank tools and straight-shank twist drills and tools. A removable pipe handle is located opposite the switch handle. The spade-type handle at the rear of the machine can be removed and replaced by a feed screw attachment if required. The drill rotates at 275 revolutions per minute under full load and 350 revolutions per minute with no load.

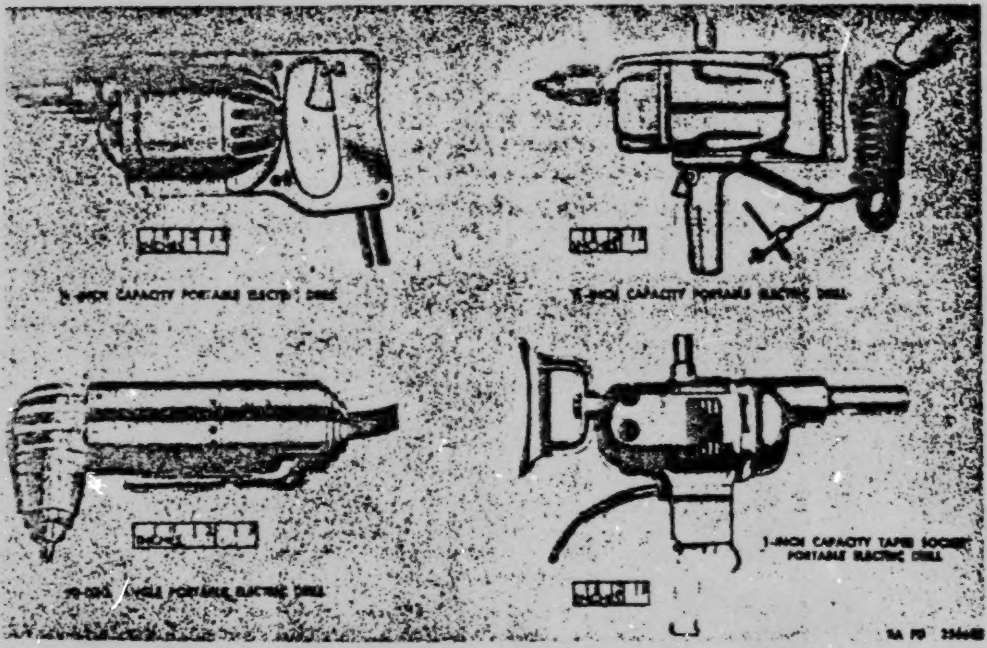

[illegible]-INCH CAPACITY PORTABLE ELECTRIC DRILL
[illegible]-INCH CAPACITY PORTABLE ELECTRIC DRILL
90-DEG ANGLE PORTABLE ELECTRIC DRILL
1-INCH CAPACITY TAPER SOCKET PORTABLE ELECTRIC DRILL
TA PD [illegible]

Figure 113. Portable electric drills.

(d) The 90° angle portable electric drill is designed for working in confined places where a standard shape drill will not have sufficient clearance. This drill has a 1/4-inch capacity in steel and will drill up to a 1/2-inch hole in hardwood. Drilling speed is 1,600 revolutions per minute under full load and 2,500 revolutions per minute without a load. The universal-type (AC/DC) electric motor is controlled by a paddle-type trigger switch that is operated by squeezing with the fingers as the hand encircles and supports the case of the drill. A geared chuck mounts straight-shank twist drills with 1/4-inch shank diameters or less.

(2) Care and safety.

(a) Lubricate movable parts before use.

(b) Tighten drill sufficiently.

(c) Avoid running drill into table or holding device.

(d) Avoid holding work by hand.

(e) Secure protective shields before operation.

(f) Do not wear loose clothes that might catch in revolving parts.

c. Drill presses. The drill press is used primarily for drilling metal, wood, and plastic. The most common types of drill press machines are the bench drill press the floor drill press, and the portable hand drills that were covered in the preceding paragraph. These machines are used in conjunction with three other tools; twist drills, chuck key, and the portable drill vise. The bench drill press and floor drill press, which are the two types discussed in this paragraph, have four general parts; base, column, table, and head assembly.

(1) Bench-type drilling machine (fig 114). The bench-type drilling machines are used for small drilling operations. They are classified as to size by the largest drill that the drill chuck will hold. Spindle speed (RPM) is adjustable through a four-step, cone pulley. Feed is controlled by the feed handle and depth of cut is controlled by the use of the depth gage rod. The table is adjustable vertically permitting work of various heights to be mounted.

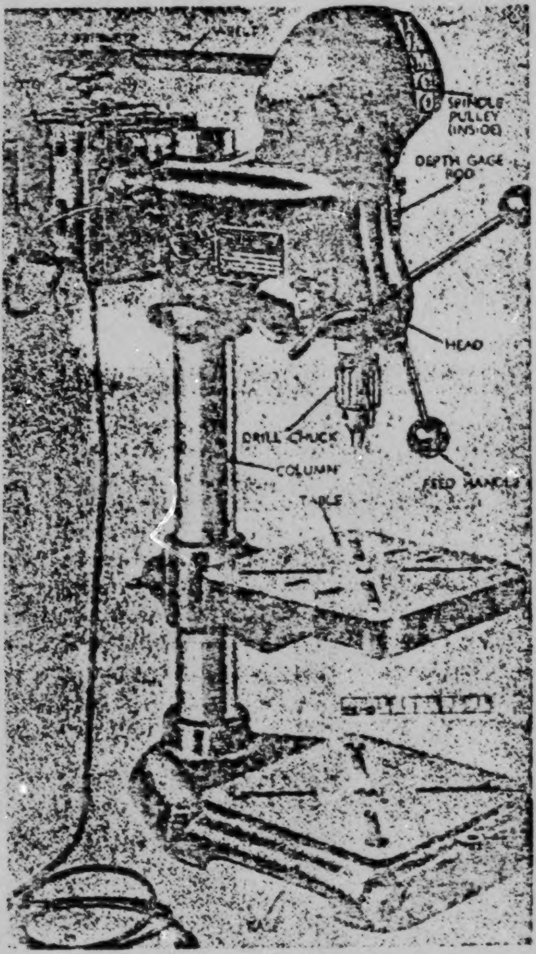


Figure 114. Bench-type drilling machine.

(2) Upright drilling machine (floor-mounted). The floor-mounted drilling machines (fig 115) are designed for workpieces that are too large to be handled on the bench-type machine. The tables on these machines can be adjusted horizontally, vertically, and tilted. The heads can also be raised, lowered, or swiveled. Models with power feed have several spindle speeds and automatic feeds.

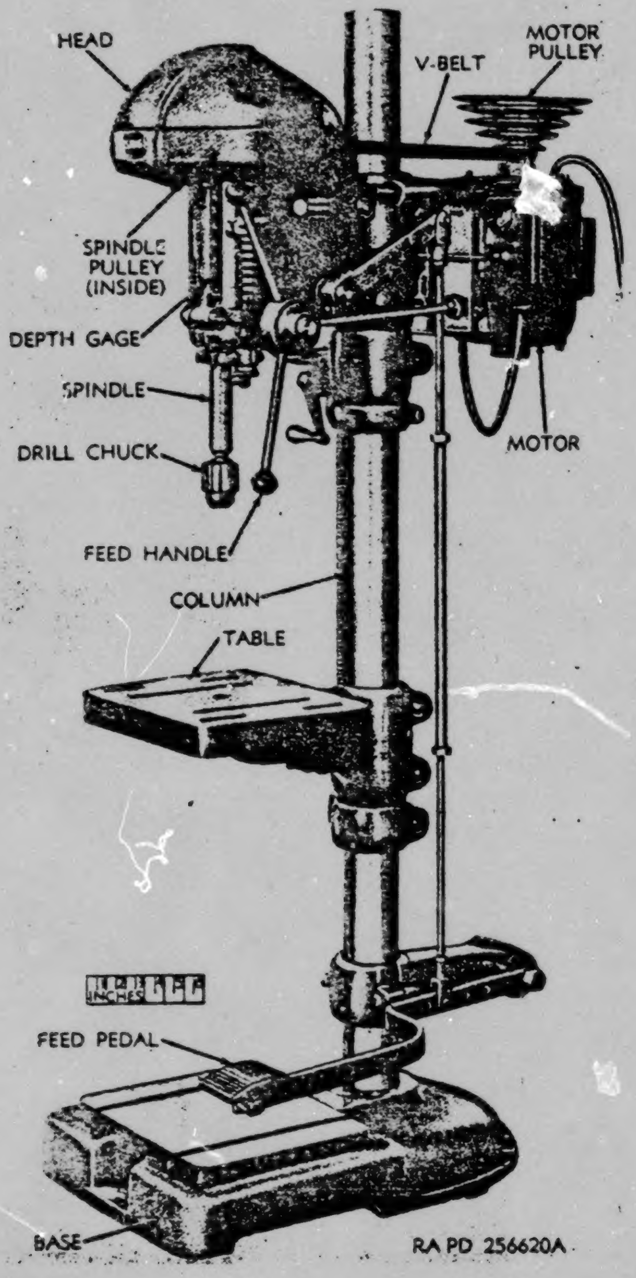

HEAD
V-BELT
MOTOR PULLEY
SPINDLE PULLEY (INSIDE)
DEPTH GAGE
SPINDLE
DRILL CHUCK
MOTOR
FEED HANDLE
COLUMN
TABLE
INCHES
FEED PEDAL
BASE
RA PD 256620A

Figure 115. Upright drilling machine (floor-mounted).

d. Hacksawing machine. The portable hacksaw (fig 11c) has a built-in AC or DC 110-volt motor that operates the blade at 115 strokes per minute. The machine has a capacity of 3-inch stock and can operate in the horizontal or vertical position. The length of the hacksaw blade used with the machine is 10 inches and the length of the cutting stroke is 4 inches. The machine will shut off automatically when the cut is finished. This machine is used to cut solid steel stock and other materials such as thin wall brass tubing

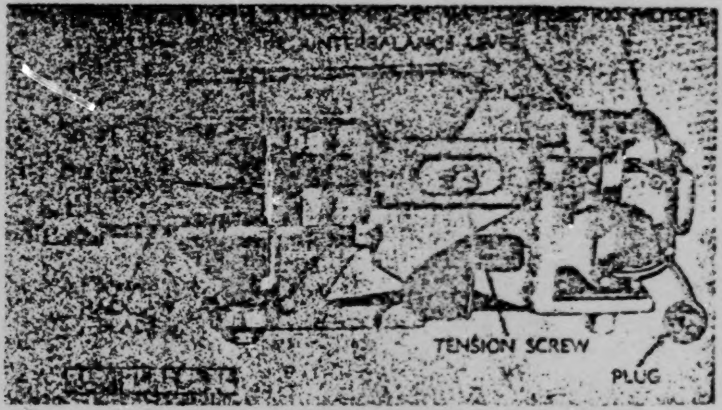


Figure 11c. Portable hacksawing machine.

SECTION IV. CONCLUSION

29. SUMMARY. This lesson has discussed some of the more common handtools used by machinists; additionally, it covered the care and use of these tools. Thus, your knowledge of handtools has increased and the proficiency of your shop operation should be enhanced due to this increased knowledge. The completed jobs that will leave your shop should be of the highest quality due to correct maintenance supervision of the equipment under your control. You should take pride in your ability to use tools more efficiently.

EXERCISE

56. Which statement in relation to machinist's hammers is true?

a. The best general purpose machinist's hammer is the cross-peen hammer
b. The flat end of a machinist's hammer is called the face
c. The rounded end of a machinist's hammer is called the claw

57. What type wrench has two jaws that are not parallel?

a. Adjustable pipe
b. Adjustable single open end
c. Combination open and box end

58. What type wrench uses interchangeable handles?

a. Box end
b. Open end
c. Socket

208

59. What type of file should be used to file the gullet between saw teeth?

   a. Triangular
   b. Pillar
   c. Square

60. What type hacksaw blade is recommended for sawing sheet metal that is thinner than 18 gage and for thin-walled tubing?

   a. Flexible blade with 32 teeth per inch
   b. Hard blade with 28 teeth per inch
   c. Flexible blade with 18 teeth per inch

61. For what purpose is a three- or four-fluted drill bit used?

   a. Enlarging cored holes
   b. Elongating holes
   c. Cutting holes in soft metal

62. When cutting sheet metal, which tool does not cause any material to be removed?

   a. Acetylene torch
   b. Tin shears
   c. Drill

63. Which operation can best be performed by using a cape chisel?

   a. Cutting V-grooves
   b. Splitting nuts
   c. Cutting keyways

64. Which is a primary use of the soft-face drift punch?

   a. Unseating bolts or pins that are extremely tight
   b. Removing bolts or pins that have been unseated
   c. Removing engine wristpins

65. What type pliers are considered as special purpose pliers?

   a. Brake spring pliers
   b. Diagonal cutting pliers
   c. Slip joint combination pliers

66. How is the size of a standard screwdriver determined?

   a. Thickness of blade
   b. Length of blade
   c. Width of blade

67. Which type vise usually has the smallest holding capacity?

   a. Machinist's bench
   b. Bench and pipe
   c. Clamp base bench

68. What is the proper name for the spiral grooves on a drill bit?

    a. Flute
    b. Lip
    c. Heel

69. What are round split adjustable dies called?

    a. Button
    b. Pipe
    c. Cap

70. Which level was designed to determine if a plane or surface is true horizontally and vertically?

    a. Striding
    b. Master precision
    c. Machinist's

71. Which is the correct way for sharpening the point of a scriber?

    a. Place scriber in a vise and sharpen the point slowly with the special crosscut file
    b. Rotate the scriber between the thumb and forefinger while moving the point back and forth on an oilstone
    c. Place the scriber in a vise and sharpen the point by circling it with a whetstone

72. By using keyseat clamps, which rule can be used for laying out keyways on the cylindrical surface of a shaft?

    a. Circumference rule
    b. Tape rule
    c. Six-inch steel pocket rule

73. What tool facilitates the measuring of angles in relation to the horizontal or vertical plane?

    a. Combination square set
    b. Inside micrometer
    c. Firm joint caliper

74. What is one of the most common uses of a try square?

    a. Determining the angle of a lathe way
    b. Determining whether sawed edges are true
    c. Laying out precision angles

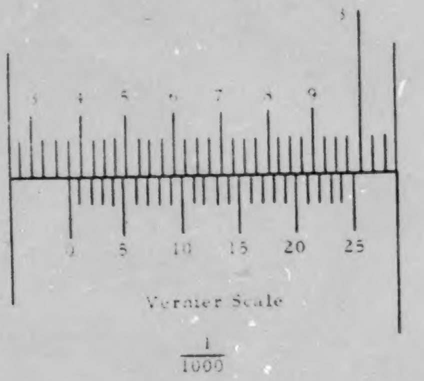
75. What tool can be used for the same purpose as a divider or caliper?

    a. Hook rule
    b. Bevel protractor
    c. Trammel

210

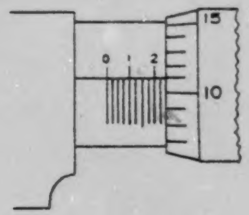
76. What is the reading (inches) on the 26-inch vernier caliper in the illustration below?

a. 2,375
b. 3.375
c. 2.325



77. What is the reading (inches))on the 6-inch micrometer below?

a. 5.261
b. 5.234
c. 5.236



78. What is a surface gage generally used for?

a. Measure hardness of metal
b. Transfer measurements to work
c. Check thickness of metals

79. What determines the size of a bench-type drilling machine?

a. Maximum size drill that the drill chuck will hold
b. Speed of rotation of the drill spindle
c. Horsepower of the drill drive motor

80. Which statement regarding a bench grinder wheel is NOT true?

a. As a rule, do not grind work requiring heavy pressure on the side of the wheel
b. A faulty grinding wheel will give off a ringing sound when tapped lightly with a mallet
c. Wear goggles even if the grinding wheel is fitted with eyeshields.

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 424	Machine Shop Practice
Lesson 5	Vertical Cutting Bandsaw
Credit Hours	One
Lesson Objective	After studying this lesson you will be able to: 1. Explain the history and development of the vertical bandsaw machine. 2. Describe bandsaw machines as to types, use, nomenclature, and operation. 3. Describe bandsaw machine accessory attachments as to types, use, selection, care, and cleaning.
Text	Attached Memorandum
Materials Required	None
Suggestions	If possible, visit a machine shop and observe the vertical cutting bandsaw in operation. Also, pay particular attention to illustrations provided.

STUDY GUIDE AND ATTACHED MEMORANDUM

1. INTRODUCTION.

a. General. Although the saw blade was developed over 2,000 years ago, no significant designs for sawing machines were made until 1803 when a practical design for a bandsawing machine was patented. This machine, designed by Newberry, had three wheels arranged in a triangular pattern upon which the bandsaw blade was driven (fig 1). The use of this early machine was hindered by imperfection of suitable continuous blade bands. In 1846, a Frenchman, named Perin, devised a satisfactory means for joining the bandsaw blade ends. The Newberry machine as well as other sawing machines developed before the end of the 19th century were used for sawing wood only.

b. Metal cutting. Hacksawing machines were developed near the turn of the century. They proved to be the first satisfactory metal cutting power-driven saws except for circular saw blades that had been in use for parting operations on the milling machine. The early hacksawing machines consisted merely of a mechanism for driving a hacksaw blade back and forth. Later, refinements were made to improve the sawing action. Devices were added to these machines to make the hacksaw blade lift on the return stroke to prevent dulling or snagging of the blade, and adjustable weights and counterbalances were added so that the feed of the machine could be controlled.

OS 424, 5-P1
October 1973

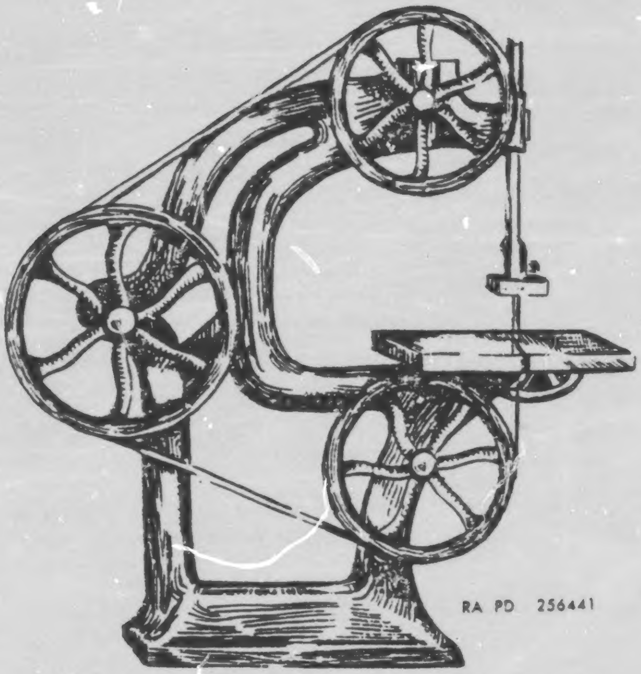


Figure 1. Newberry's bandsawing machine — 1803.

c. Bandsaws. The metal cutting bandsawing machine was developed after the hacksawing machine, although the wood cutting bandsawing machine had been used for close to a century at that time. Where the hacksawing machine was restricted to square or angle cutting of stock, the metal cutting bandsawing machine could perform intricate contour cutting of shapes from steel plate.

d. Modern hacksaws. Later advances to the hacksawing machine design have not changed the original concept of the machine. The modern hacksawing has ajustable cutting speeds and stroke lengths. Some of the newer machines have borrowed the quick-return mechanism of the shaper so that the sawing action can be increased without increasing the blade speed. The large production-type hacksawing machines have automatic feed devices whereby a bar or a number of bars of stock can be fed into the machine, clamped in the vise, and cut automatically.

e. Modern bandsaws. The modern bandsawing machine has variable saw blade speeds so that any metal, hard or soft, can be cut successfully. These machines incorporate power feed devices and are usually equipped with a number of accessories by which filing, polishing, circle cutting, and internal cutting can be performed. The bandsaw blade ends are butt welded to form a joint that will not interfere with the sawing of the workpiece. Many metal cutting bandsawing machines contain built-in butt welders so that blade bands may be formed at the machine.

2. BANDSAWING MACHINES.

a. Description. Metal cutting bandsaw machines fall into two basic categories, horizontal machines and vertical machines. The vertical bandsawing machine is the one that is most commonly used (fig 2). On this machine, the blade in its cutting position is vertical and it cuts into the side of the stock. The blade rotates on a fixed track, the idler wheel being mounted above the worktable and the drive wheel being mounted beneath the worktable. The stock is moved against the blade to make the cut. On the horizontal bandsawing machine, the bandsaw blade in its cutting position is horizontal and cuts downward into the stock. The drive and idler wheels are positioned lengthwise on the sawing machine frame which pivots from a corner of the sawing machine bed. With the horizontal machine, the stock is fixed rigidly in a vise to the bed of the machine, and the bed is fed downward into the workpiece. The horizontal bandsawing machine is used primarily for cutting stock to length, either at right angles or to any desired miter angle. The vertical machine is more versatile and can be used for contour cutting, filing, and polishing, as well as simple cutting of stock.

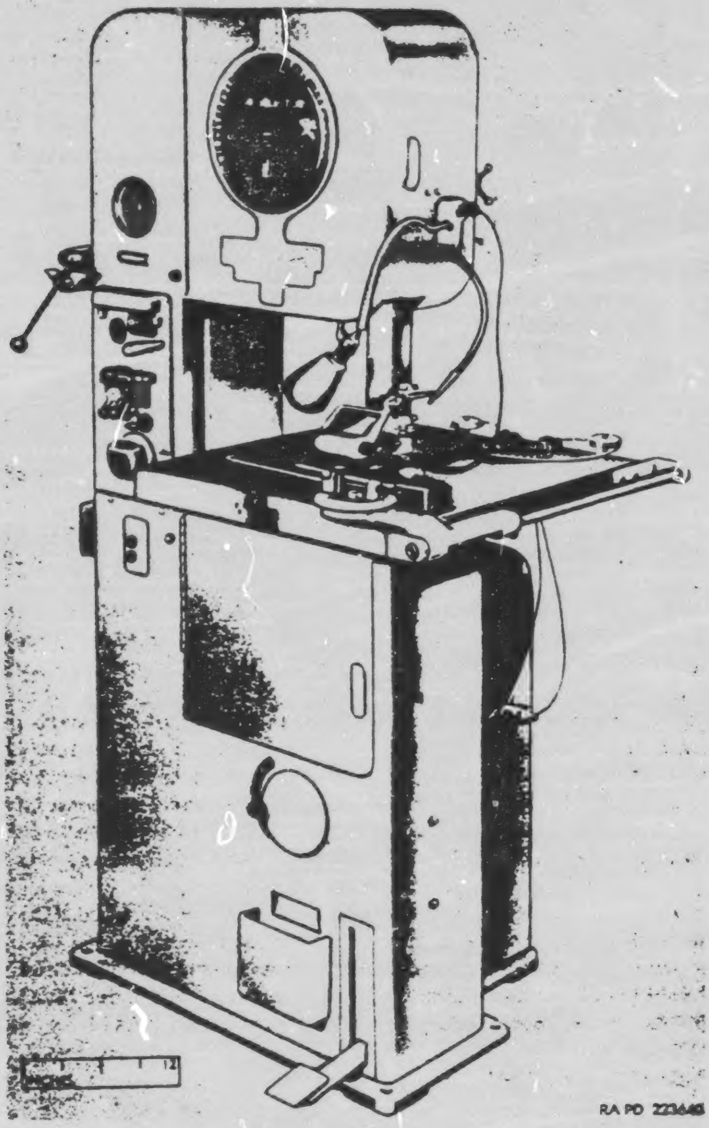


Figure 2. Metal cutting bandsawing machine.

b. Metal cutting bandsawing machine. The metal cutting bandsawing machine (fig. 2) is a vertical machine. Being much more common than horizontal machines, vertical bandsawing machines are usually identified as "bandsawing machines" without using the word "vertical" in their descriptions. The machine illustrated in figure 2 is driven by a 3/4-horsepower electric motor through a belt transmission which permits adjustable blade speeds from 50 feet per minute to 1,500 feet per minute, although other bandsawing machines have speed ranges up to 2,000 feet per minute. The table may be tilted front-to-back or sideways to cut mitered edges. The metal cutting bandsawing machine does not require preformed bandsaw blade bands. An electric butt welder and grinding wheel are built into the sawing machine column. The welder is used to weld a length of blade into a continuous band, and the grinding wheel is used to remove beads caused by the welding. Since the machine can weld its own blade bands, internal cutting is possible. In this case the blade is inserted through a hole cut in the workpiece and then the blade is welded into a band and mounted to the machine. After cutting the internal shape in the piece, the band is cut so that it can be removed. An attachment for the metal cutting bandsawing machine twists the bandsaw blade 30° or 90° so that stock which normally could not be cut because of insufficient clearance of the sawing machine column can be successfully cut. Other attachments permit the use of band files and polishing bands in place of the bandsaw blade. Adjustable guides for holding and feeding workpieces are also provided. The machine has a power feed mechanism operated by counterweights. Forced air for cooling and chip removal is supplied by an air pump in the base of the machine.

3. BANDSAW BLADES.

a. General. Bandsaw blades are manufactured in two forms. They are supplied in rolls of 50 to 400 feet for use on machines that have butt welders for forming their own blade bands and are also supplied in continuous welded bands in standard sizes for machines having no provisions for welding blade bands.

b. Materials. Bandsaw blades are made from special alloy steels. The blades are made flexible by annealing the body of the blade and hardening only the teeth. Most metal cutting bandsaw blades are not capable of being sharpened but there are some coarse tooth blades commercially available which are made of Swedish steel and have coarser teeth than usual which can be resharpened like wood-cutting bandsaw blades.

c. Setting of teeth. Metal cutting bandsaw blades have their teeth set to produce a kerf, or cut, slightly wider than the thickness of the blade to prevent the blade from being pinched by the stock. The setting of the teeth for most bandsaw blades is called the raker setting. Raker tooth blades have one tooth bent over to the right, the next tooth bent over to the left, and the third tooth set straight (fig. 3). This pattern is especially suitable to blades that cut at high speeds.

d. Pitch of teeth. The pitch of bandsaw blade teeth (fig. 3) is the number of teeth per linear inch of the blade. For example, if a blade has 14 t.p.i (teeth per inch), it has a pitch of 14, or it may be stated as being a 14-pitch blade. Metal cutting bandsaw blades range from 6 to 32 teeth per inch; the finer tooth blades being used for sawing thin stock, and the coarse tooth blades being used for sawing large stock and soft metals.

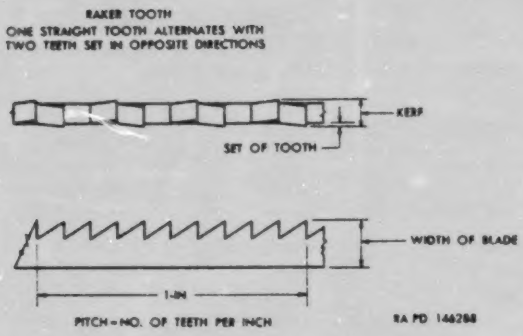

RAKER TOOTH
ONE STRAIGHT TOOTH ALTERNATES WITH TWO TEETH SET IN OPPOSITE DIRECTIONS
KERF
SET OF TOOTH
WIDTH OF BLADE
1-IN
PITCH—NO. OF TEETH PER INCH
RA PD 146288

Figure 3. Characteristics of bandsaw blades.

e. Selection of bandsaw blades.

(1) Bandsaw blades are selected according to the type of material to be cut, the thickness of the material to be cut, and the sawing operation to be performed.

(2) Soft or gummy materials and thick stock require coarse tooth blades to provide adequate chip clearance. Hard materials generally require finer tooth blades. Fine tooth blades are also necessary if a good finish is desired.

(3) Two or three teeth of the bandsaw blade must be in contact with the workpiece at all times to prevent chatter and shearing off of teeth (fig. 4). Therefore, fine tooth blades are used to cut sheet metal and tubing. If sheet metal is too thin to meet this requirement with the finest tooth blade available, the metal should first be mounted on plywood, fiber, or thicker metal to stiffen it.

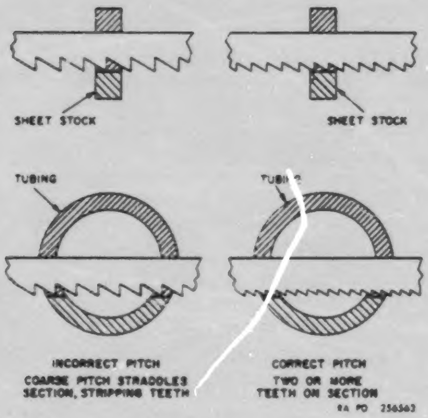

SHEET STOCK
SHEET STOCK
TUBING
TUBING
INCORRECT PITCH
COARSE PITCH STRADDLES SECTION, STRIPPING TEETH
CORRECT PITCH
TWO OR MORE TEETH ON SECTION
RA PD 256563

Figure 4. Correct and incorrect pitch.

(4) Table I is provided as a guide in selecting the proper pitch bandsaw blade for different metals and metal thicknesses. If the stock is exceptionally large, coarser tooth blades than those recommended for solid stock may be used.

TABLE I. SELECTION OF BANDSAW BLADES

Material	Bandsaw blade (tpi)	Material	Bandsaw blade (tpi)
Sheet metal, under 1/8 inch thick	24-32	Solid stock [1]—Continued	
Sheet metal, over 1/8 inch thick	18	Steel, alloy	12-14
Solid stock:[1]		Steel, high-speed	12-14
Aluminum	6-10	Steel, machine	10-14
Brass	10-12	Steel, stainless	12-14
Bronze	12-14	Steel, tool	12-14
Cast iron	10-12	Tubing, under 1/8-inch wall thickness	24-32
Copper	10-12	Tubing, over 1/8-inch wall thickness	18

[1] Two or more teeth must contact the workpiece at all times to prevent shearing of the blade teeth. If the recommended pitch for solid stock fails to meet this requirement, a blade with finer pitch must be selected.

(5) For straight sawing, the widest blade available of the proper pitch should be used. Narrower blades are required for contour sawing to prevent the body of the blade from rubbing the sides of the cut when cutting sharp curves. When curves or radii are to be cut on the bandsawing machine, the widest blade adaptable to the sharpest radius to be cut should be used. Narrow blades are much more easily broken than wide blades and should be used only where necessary. Table II lists blade sizes which can be used for cutting different size radii.

TABLE II. BANDSAWING RADIUS GUIDE

Radius to be cut (in.)	Width of bandsaw blade to use[1] (in.)	Radius to be cut (in.)	Width of bandsaw blade to use[1] (in.)
2-1/2 and larger	1/2	5/8 to 15/16	1/4
1-7/16 to 2-7/16	3/8	5/16 to 9/16	3/16
1 to 1-3/8	5/16	1/8 to 1/4	1/8

[1] If the proper size blade for the radius to be cut is not available, the next size narrower blade should be used

f. Bandsaw blade wear.

(1) Bandsaw blades become dull naturally from prolonged use, but some conditions promote greater than normal wear on the blades. Blades dull quickly if used at too high a speed for the material being cut. Also, if the material to be cut is too hard for the pitch of the blade, abnormal wear will result. This can be caused by hard spots in cast iron or welded metal and usually can be anticipated so that the operator can reduce the feed. Rubber and some fibers or plastics contain abrasive material that will dull saw blades regardless of the sawing speed and feed. Premature blade dulling often occurs from using too fine a pitch blade and from feeding too heavily.

(2) The following symptoms indicate a dull bandsaw blade and when noticed, the blade should be replaced.

(a) The bandsaw blade cuts slowly or not at all when the workpiece is fed by hand.

(b) The teeth of the blade are bright on the cutting edge.

(c) It becomes difficult to follow a line; the blade forces to one side or the other.

(d) The chips cut by the bandsaw blade are granular on metals other than cast iron which always produces granular chips.

(e) With the machine stopped, or the bandsaw blade removed from the machine, run a finger slowly over the teeth in the cutting direction. Sharp edges cannot be felt.

4. FILE BANDS.

a. General. The metal cutting bandsawing machine is adapted for filing operations by use of the band file attachment. A band file is then fitted over the drive and idler wheels in place of the bandsaw blade. Band files (fig. 5) consist of many interlocking file segments that are riveted to flexible steel bands. These bands are attached to each other, end to end, to form a continuous band. The file segments are attached to steel bands in such a manner that they form a continuous filing surface when held in a straight line, but separate from each other as they move about the idler and drive wheels. The band file attachment provides a support behind the file above the table so that the band file cannot be forced backward by the pressure of the workpiece as it is filed.

b. Cut of file teeth.

(1) Most files are classed as single-cut or double-cut files according to the kind of teeth. Single-cut files have rows of parallel teeth extending across the face of the file at an angle. Double-cut files have two rows of parallel teeth which cross each other. The first row, usually cut at about a 45° angle, is coarser and deeper than the second row which is generally cut at an angle of from 70° to 80°. Band files are always of the double-cut type.

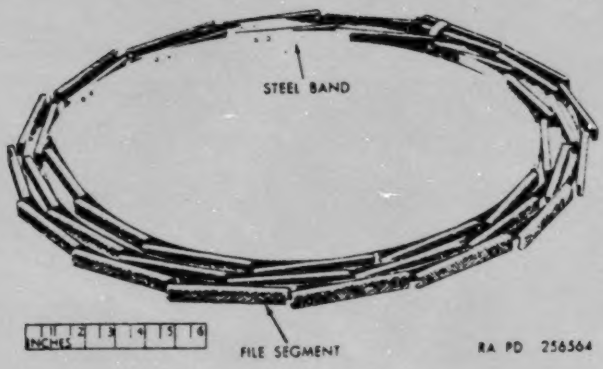


Figure 5. Band file.

(2) Double-cut files of medium pitch are called bastard-cut files. These files usually have between 12 and 24 teeth per inch. Bastard-cut band files are commonly used for filing of steel and other hard metals on the bandsawing machine.

(3) Short angle-cut files are double-cut files in which the two rows of teeth have been cut at shorter angles than those of the bastard-cut file. Short angle-cut files are usually of coarse pitch having 10 or 11 teeth per inch. Short angle-cut band files are commonly used for filing soft metals on the bandsawing machine.

c. Band file shapes. Band files are manufactured in flat and oval shapes. Flat band files are used for the majority of filing jobs. Oval band files have a curved face and are used for filing inside curves and contours. Band files of the flat and oval shapes are made in widths of 1/4, 3/8, and 1/2 inch.

d. Selection of band files.

(1) Band files should be chosen on the basis of workpiece thickness and kind of material to be filed.

(2) In general, as the workpiece becomes thicker, the file should be more coarse. This is due to a larger total chip accumulated from thick pieces, thus requiring additional space for the chips between the teeth. On thin sheet metal, a fine pitch file is required to prevent chatter.

(3) Narrower fine pitch files should be used for tough carbon and alloy steels; wider and coarser pitch files should be used for softer, more free-cutting materials such as cast iron and nonferrous metals.

(4) Table III is provided to aid in selecting the proper file for specific materials. If sheet metal is to be filed, a finer tooth file should be used if necessary to reduce chatter and to produce a better finish on the workpiece.

TABLE III. SELECTION OF BAND FILES

Material	Band file	
	Cut of teeth	Teeth per inch
Aluminum	Short angle- or bastard-cut	10-12
Brass	Short angle- or bastard-cut	10-12
Bronze	Short angle- or bastard-cut	10-12
Cast iron	Short angle- or bastard-cut	10-12
Copper	Short angle- or bastard-cut	10-12
Fiber	Short angle- or bastard-cut	10-12
Magnesium	Short angle- or bastard-cut	10-12
Steel, alloy	Bastard-cut	14-24
Steel, machine	Bastard-cut	14-16
Steel, tool	Bastard-cut	14-24

e. Care and cleaning of band files.

(1) The particles of metal removed by the file often lodges in the file teeth, reducing the cutting efficiency of the file and affecting the quality of the finish. If hard metal particles are thus lodged, the workpiece may be scratched by these particles.

(2) When steel is to be filed, chalk can be rubbed into the file before starting. This chalk will reduce the tendency for hard particles to adhere to the file.

(3) Clean the file often using a stiff brush or a file card. The brush should be moved in the direction of each cut of the file to dislodge all particles between the teeth.

5. POLISHING BANDS.

a. General. Polishing operations can be performed on the metal cutting bandsawing machine upon installation of the polishing attachment and substitution of a polishing band for the bandsaw blade. The polishing band is usually 1 inch wide and has a heavy fabric backing.

b. Types. Polishing bands for bandsawing machines are usually supplied in three grain sizes of aluminum-oxide abrasive: No 50 grain (medium) for light grinding operations, No 80 grain (medium-fine) for coarse polishing operations, and No 120 or No 150 grain (fine) for fine polishing operations. These are preformed in continuous bands and in the appropriate sizes to fit the machine.

c. Selection. Polishing bands should be selected according to the particular job to be performed. For general removal of toolmarks and smoothing of edges, the No 50 grain polishing band should be used. This band will remove small amounts of metal by grinding and is not in the true sense of the word a polishing band. When finer grain polishing bands are used on the bandsawing machine, soft metals like aluminum or cast iron should not be polished, or the band will quickly fill with metal particles and reduce the cutting action of the polishing band.

6. ATTACHMENTS FOR METAL CUTTING BANDSAWING MACHINE.

a. Band file (fig. 6).

b. Polishing (fig. 7).

c. Disk cutting saw (fig. 8).

d. Angular blade guide (fig. 9).

e. Miter guide (fig. 10).

f. Screw feed device (fig. 11).

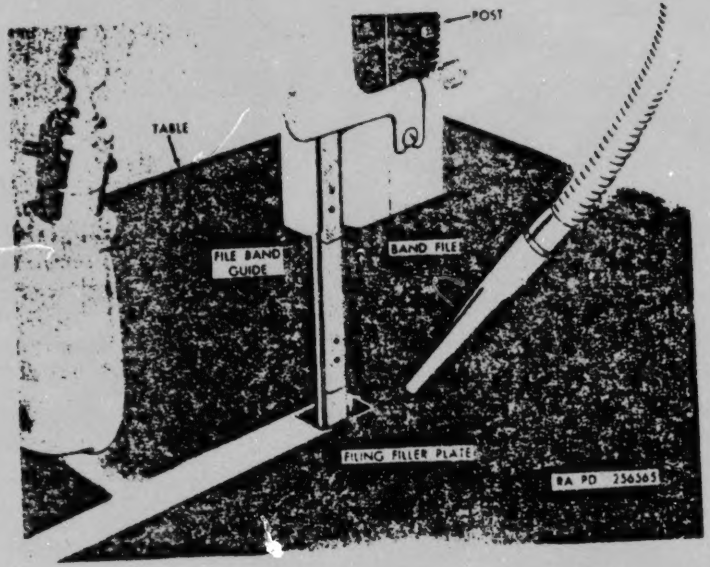

POST
TABLE
FILE BAND GUIDE
BAND FILE
FILING FILLER PLATE
RA PD 256365

Figure 6. Band file attachment installed on bandsawing machine.

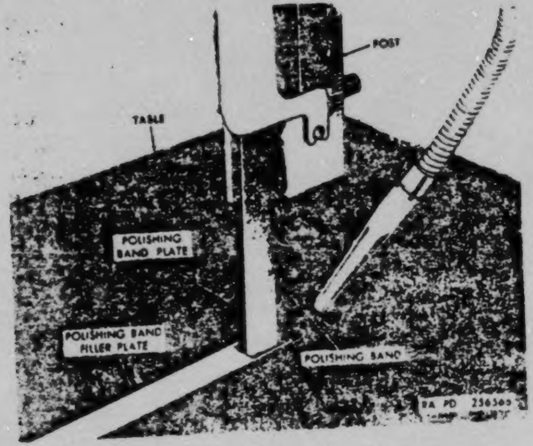

POST
TABLE
POLISHING BAND PLATE
POLISHING BAND FILLER PLATE
POLISHING BAND
RA PD 256366

Figure 7. Polishing attachment installed on bandsawing machine.

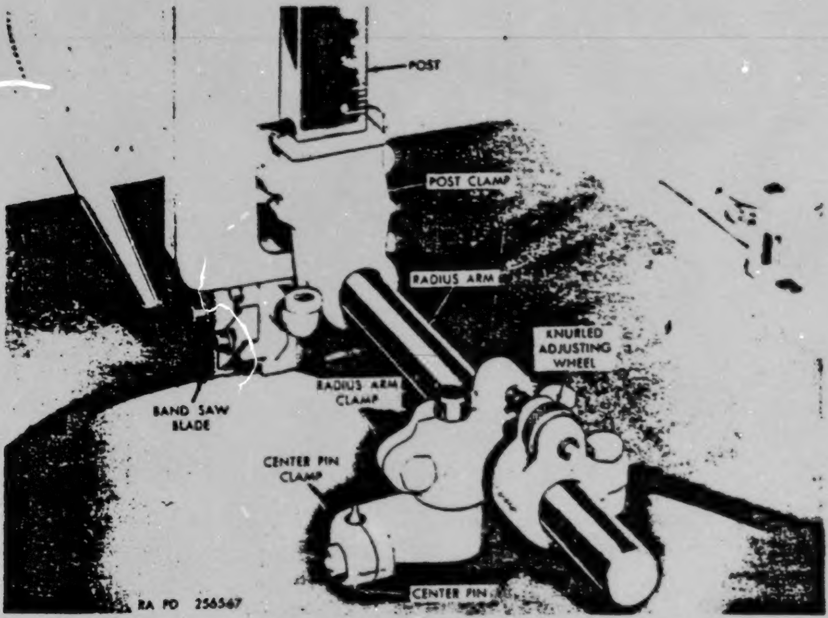

POST
POST CLAMP
RADIUS ARM
KNURLED ADJUSTING WHEEL
RADIUS ARM CLAMP
BAND SAW BLADE
CENTER PIN CLAMP
CENTER PIN
RA PD 256567

Figure 8. Disk cutting saw attachment installed on bandsawing machine.

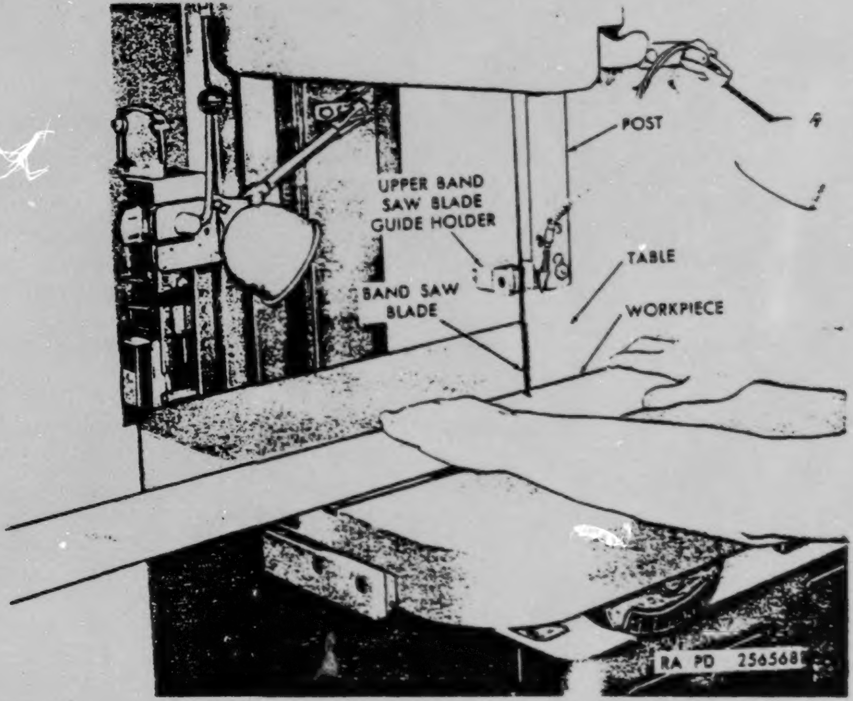

POST
UPPER BAND SAW BLADE GUIDE HOLDER
TABLE
BAND SAW BLADE
WORKPIECE
RA PD 256568

Figure 9. Sawing operation using the angular blade guide attachment.

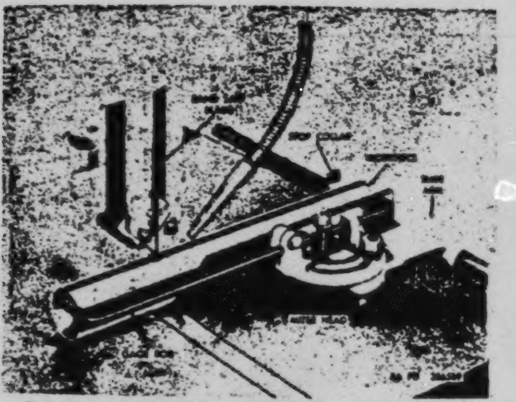


Figure 10. Sawing operation using the miter guide attachment.

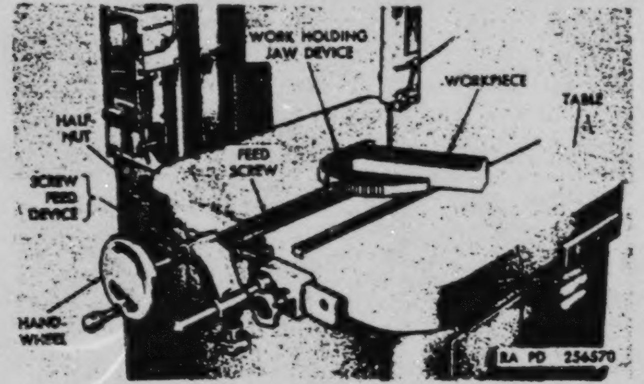


Figure 11. Sawing operation using the screw feed device.

7. FEEDS AND SPEEDS FOR BANDSAWING.

a. General. The cutting speed of a bandsawing machine is the speed of the bandsaw blade as it passes the table, measured in feet per minute. The feed of horizontal bandsawing machines is the downward movement or pressure applied to the material being cut by the bandsaw blade. The feed of (vertical) bandsawing machines is the pressure applied to the bandsaw blade by the material being cut.

b. Bandsawing speeds.

(1) Proper bandsawing speeds are important in conserving bandsaw blades. Too great a speed for the material being cut will cause abnormally rapid blade wear, while too slow a speed will result in inefficient production.

(2) Most metal cutting bandsawing machines have several cutting speeds which can be selected. Since the diameter of the drive wheel of the bandsawing machine establishes a fixed ratio between the motor or transmission speed in revolutions per minute to the blade speed in feet per minute, it is not necessary to convert revolutions per

minute into feet per minute as with most other machine tool operations. The speeds are identified in feet per minute on the sawing machine speed selector controls. Some machines have a speed indicator with which careful checks may be made of sawing speeds when the machine is operating with or without a load.

(3) In general, the following principles apply to speeds of bandsaw blades.

(a) The harder the material, the slower the speed; conversely, the softer the material, the faster the speed.

(b) The tougher or more fibrous the material, the slower the speed.

(c) The faster the speed, the finer is the finish produced on the cut surfaces. This principle applies to light feeds in conjunction with fast speeds.

(4) Refer to table IV for recommended sawing speeds for different materials. Generally the faster speeds should be used for thin material and the slower speeds should be used for thick material.

TABLE IV. BANDSAWING SPEEDS

Material	Bandsawing speed (f.p.m.)	Material	Bandsawing speed (f.p.m.)
Aluminum	200 to 2,000	Rubber, hard	150 to 250
Bakelite	200 to 900	Steel, alloy	50 to 100
Brass, soft	175 to 300	Steel, high carbon	50 to 100
Brass, hard	75 to 150	Steel, high-speed	50 to 90
Brass, sheets	200 to 900	Steel, machine	75 to 175
Bronze	75 to 150	Steel, sheet	150 to 200
Cast iron	50 to 100	Steel, stainless	50 to 75
Copper	115 to 175	Steel, tool	50 to 150
Monel metal	50 to 100		

8. (VERTICAL) BANDSAWING MACHINE OPERATION.

a. Straight-line sawing is performed on the metal cutting bandsawing machine by using one or a combination of several mechanisms or attachments. These include the miter guide attachment with or without power feed, the screw feed device with or without the work holding jaw device, the work holding jaw device with power feed, and the angular blade guide attachment.

(1) The miter guide attachment on some machines can be connected to the power feed mechanism and on others must be fed by hand. The workpiece is clamped or hand-held against the miter guide attachment and the workpiece and attachment are moved against the bandsaw blade. The miter guide assembly moves on a track parallel to the blade, thereby assuring a straight-line cut.

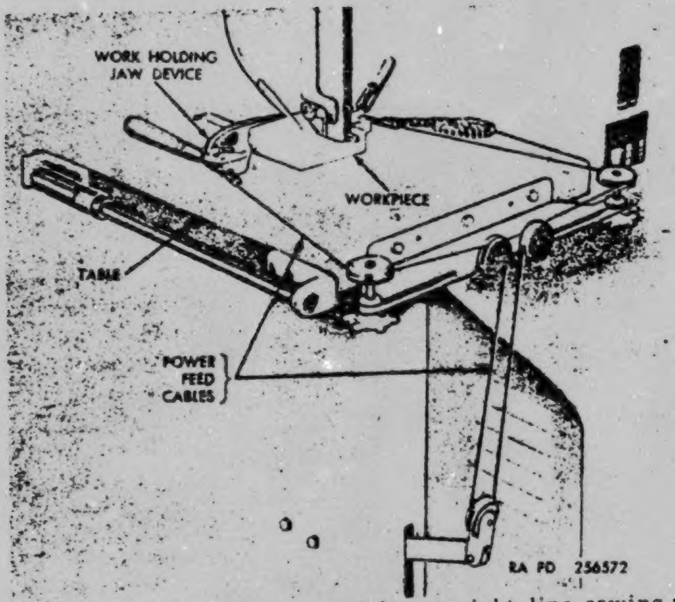


Figure 12. Work holding jaw device used for straight-line sawing with power feed.

(4) The angular blade guide attachment is used for straight-line sawing when the workpiece cannot be cut in the normal manner because it is too large or too long to clear the column of the bandsawing machine frame. When the angular blade guide attachment is used, the piece must be guided and fed by hand.

b. A typical example of a straight-line sawing operation is outlined below.

(1) Select a bandsaw blade of the desired pitch for the nature of material to be cut. The blade should be as wide as possible for straight-line sawing.

(2) Set the desired speed on the bandsawing machine.

(3) Position the workpiece at the desired angle in one of the bandsawing machine attachments and connect the cable to the power feed mechanism if power feed is to be used.

(4) Start the bandsawing machine and feed the workpiece lightly into the blade to start the cut. Once the cut is started, the feed can be increased. If feed is by hand, the pressure applied to the workpiece by the operator can be varied to find the best cutting conditions.

9. COOLANT.

a. The sawing machines used in the Army are usually dry-cutting machines; that is, they are not intended for use with liquid cutting oils.

b. The metal cutting (vertical) bandsawing machines contain air pumps and hoses through which a jet of air is directed against the bandsaw blade and workpiece. The air acts as both a coolant and as a means of removing chips from the cutting area. The nozzle of the air hose should always be directed at the contact area of the blade and workpiece.

10. SPECIAL OPERATIONS ON SAWING MACHINES.

a. Band filing.

(1) General. Filing operations are performed on the metal cutting bandsawing machine using a band file and the band file attachment. As with sawing operation, the quality of filing and the economical wear of the band file depend upon proper selection of files and filing speeds for different materials and conditions.

(2) Band filing speed. Band files should be run at relatively slow speeds as compared to speeds used for bandsawing. Table V lists recommended filing speeds for band filing. Note that, in general, the slower speeds are used for filing harder metals and faster speeds are used for filing softer metals.

(3) Band filing feeds. Work pressure on the band file should not be excessive. A medium amount of pressure applied against the band file moving at the proper speed will produce curled chips which will not clog the file. Heavy pressure will cause clogging and can cause breaking of the file or stalling of the machine. A light pressure should be used for finish filing, with a slow sideways motion that will not leave vertical file marks on the workpiece.

TABLE V. BAND FILING SPEEDS

Material	Band filing speed (f.p.m.)	Material	Band filing speed (f.p.m.)
Aluminum	75 to 175	Fiber	115 to 175
Brass	115 to 260	Magnesium	75 to 175
Bronze	75 to 115	Steel, alloy	50 to 115
Cast iron	50 to 115	Steel, machine	75 to 175
Copper	115 to 260	Steel, tool	50 to 75

b. Polishing.

(1) General. Polishing bands and a polishing attachment are provided with the metal cutting bandsawing machine so that light polishing operations can be performed. The polishing bands are intended primarily for the removal of saw marks on the cut edges of the workpiece.

(2) Polishing speeds. Polishing bands should be moved at speeds between 75 and 260 feet per minute, the faster speeds being used for softer materials and the slower speeds being used for harder materials.

(3) Polishing feeds. Feeds should be light for polishing operations. Use a slow sideways motion so that the polishing band will leave no marks on the workpiece. If the band does not remove the toolmarks quickly, change to a coarser polishing band.

11. SUMMARY. The history, development, and types of metal cutting bandsawing machines have been discussed. You have learned the proper method of selecting blades, proper speeds to be used, and symptoms of dull blades. Polishing and filing with the metal cutting bandsaw machines were also discussed. The knowledge you have learned from this lesson will improve your efficiency as well as the efficiency of your shop.

EXERCISE

81. What operation has to be performed after an internal cut has been completed?

a. Cut saw blade
b. Twist band out of cut
c. Raise column

82. What cools the workpiece during the cutting operation?

a. Turpentine
b. Kerosene
c. Air

83. What type bandsaw teeth can be resharpened?

a. Coarse
b. Medium fine
c. Medium

84. What type setting is used on most metal cutting bandsaw blades?

a. Negative
b. Positive
c. Raker

85. What pitch is BEST suited for cutting 1/32-inch sheet metal stock?

a. 32
b. 16
c. 12

86. What width bandsaw blade (inches) should be used to cut a 5/16 to 9/16 radius?

a. 5/16
b. 1/4
c. 3/16

87. Which characteristic is the same for all bandsaw files?

    a. Single-cut
    b. Double-cut
    c. Bastard-cut

88. Why should a coarse file be used on thick stock?

    a. Prevents chatter of the workpiece
    b. Covers more area in a shorter time
    c. Allows for chip accumulation

89. When steel is to be filed, which substance rubbed into the file will reduce the tendency of hard particles to adhere to it?

    a. Chalk
    b. Light oil
    c. Turpentine

90. What bandsaw speed (FPM) should be used for cutting soft brass?

    a. 50-75
    b. 75-150
    c. 175-300

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 424. . . . . .Machine Shop Practice

Lesson 6 . . . . .Shaper

Credit Hours . . . . .One

Lesson Objective . . . . .After studying this lesson you will be able to:

1. Discuss shapers as to history, types, use, nomenclature, capabilities, and operation.
2. Discuss shaper accessory attachments to include cutting tools, cutting tool holders, swivel vise, rotary table, and indexing fixture as to types, use, and mountings.
3. Explain various shaper functions such as setting cutting speeds and strokes, horizontal planing, angular planing, internal slotting, and planing irregular surfaces.

Text . . . . .Attached Memorandum

Materials Required . . . . .None

Suggestions . . . . .Visit an industrial plant or technical or vocational high school and observe a shaper in operation.

STUDY GUIDE AND ATTACHED MEMORANDUM

1. INTRODUCTION.

a. General. Shapers and planers were developed during the early part of the 19th century to do the work of the hammer and chisel in producing flat surfaces on workpieces. Between 1814 and 1825 several independent inventors in England constructed planers. Richard Roberts and Richard Platt were two of these inventors. Roberts machine (fig 1), constructed in 1817, had a chain-drive worktable which was reciprocated manually through a crank at the side of the machine. The cutting tool was fixed to a cross slide supported above the worktable on upright columns projecting from the bed of the frame of the machine. Another planer of the period, perhaps the predecessor of the shaper, was a sturdy wall-mounted machine where the workpiece remained stationary and the cutting tool and toolhead moved across the workpiece on a track fixed to a brick wall.

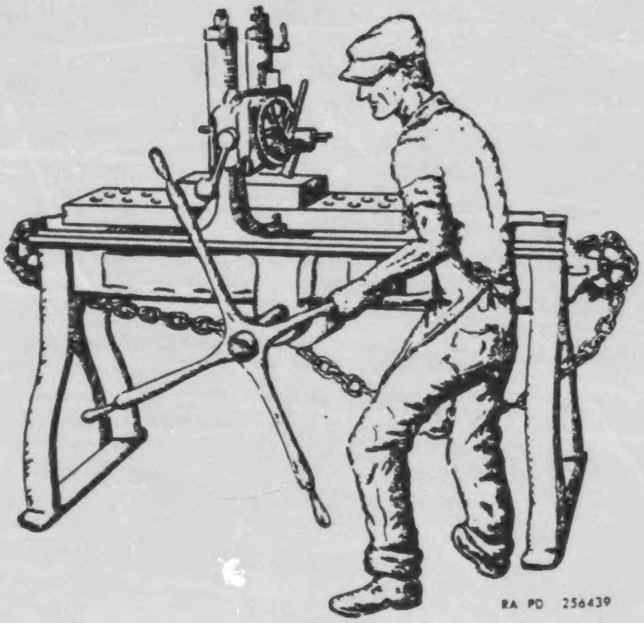


Figure 1. Robert's planer—1817.

b. The steel arm. The first shaper was invented by James Nasmyth in 1836 and featured a reciprocating arm that carried the cutting tool over a fixed workpiece to make the cut. This machine tool was referred to at that time as "Nasmyth's Steel Arm."

c. Development. Joseph Whitworth of England, a brilliant inventor who was the founder of methods of precision in the working of metals, made major improvements to the early shapers and planers before 1850. He developed a quick-return reciprocating action for the shaper and planer by which the shaper ram and the planer worktable would speed up on their return strokes, thus shortening the time required for shaping or planing operations. Before this time, experimental planers had been fitted with double toolheads which would cut on both the forward and backward strokes. This method did not prove practical. Another improvement of this period was the enlarging of the planer bed. On the first planer, the worktable invariably overhung each end of the bed at the end of each stroke. The overhang caused the worktable to spring downward under pressure from the cutting tool, thereby decreasing the accuracy of the cut. The early chain-drive from the planer worktable was replaced by a rack and pinion, the rack being fixed to the underside of the worktable. An American, Sellers, drove the rack by a worm which was positioned diagonally across the planer bed. This driving device is still in use today.

d. Improvements. Improvements to shapers and planers since 1900 have been chiefly engineering design advances to improve the rigidity of the machine tool, increase the accuracy of operation, and make the machines more versatile and more automatic. The spur gears used to drive the racks of planers were replaced by helical tooth gears which drive the planers much more smoothly. On large planers and shapers, the introduction of hydraulic cylinders to operate the worktable or ram further improved the smoothness of operation and provided much wider range of cutting speeds. The development of carbide-tipped cutting tools allowed a further increase in production from heavy-duty planers which perform some of the largest metal cutting operations today.

2. SHAPERS.

a. Purpose. Shapers are machine tools used principally for the production of flat and angular surfaces on metal workpieces. Shapers are restricted to the machining of small and medium size workpieces.

b. Operation. The shaper uses a reciprocating ram to push and pull the single-edge cutter bit across the face of the workpiece. The ram on all shapers, except specialized shapers, moves in a horizontal direction. The cutting action of the cutter bit is on the forward stroke of the ram, which is delivered at a slower speed than the return stroke. The workpiece, which is mounted to the shaper table, moves sideways after each forward stroke of the ram to aline the workpiece for the next cut. The size of a shaper is designated by the maximum length of its stroke; thus, a 16-inch shaper will machine workpieces up to 16 inches in length.

3. TYPES OF SHAPERS.

a. General. The most common shapers in use are the horizontal shapers in which the ram moves back and forth horizontally on the top of the shaper column. Most horizontal shapers have either a crank drive mechanism or a hydraulic drive mechanism. In crank-driven horizontal shapers, the crank drive mechanism is used to change rotary motion to reciprocating motion. A large gear, called a bull gear, receives a rotary motion from the electric motor. A crankpin, mounted eccentrically to the bull gear, drives a rocker arm back and forth as the bull gear rotates. The rocker arm, pivoting from the shaper base drives the ram back and forth. With hydraulic horizontal shapers, the ram is moved back and forth by a piston moving in a cylinder under the ram. Oil pressure in the cylinder is controlled to act first against one side of the piston and then against the other side to give the ram a positive drive.

b. Bench-mounted horizontal metal cutting shaper. The bench-mounted horizontal metal cutting shaper (fig 2) has a crank-driven ram with a maximum stroke of 7 inches. The shaper is powered by a 1/3 horsepower electric motor which is connected to the bull gear by V-belts and pulleys. The drive pulley V-belt can be shifted to give speeds ranging from 40 to 180 strokes per minute. The stroke can be adjusted to any length up to 7 inches, and the ram can be adjusted in relation to the shaper table for centering the stroke over the workpiece. The crossrail, located across the front of the shaper frame, supports the shaper table and permits lateral and vertical movement of the table. Workpieces can be mounted directly to the shaper table or held in a swivel vise, shaper rotary table, or indexing fixture attached to the shaper table.

4. SHAPER CUTTING TOOLS.

a. General. The single-edge cutting tools used for shaper work are called cutter bits and are similar to the cutter bits used for lathe cutting. Shaper cutter bits are made of high-speed steel or may consist of a mild steel shank with an inserted carbide or high-speed steel tip. Interchangeable cutter bits ground for different cutting operations are easily fastened to the shaper toolpost or to a cutter bit toolholder. The cutter bit may be mounted at different angles depending on the nature of the cutting operation.

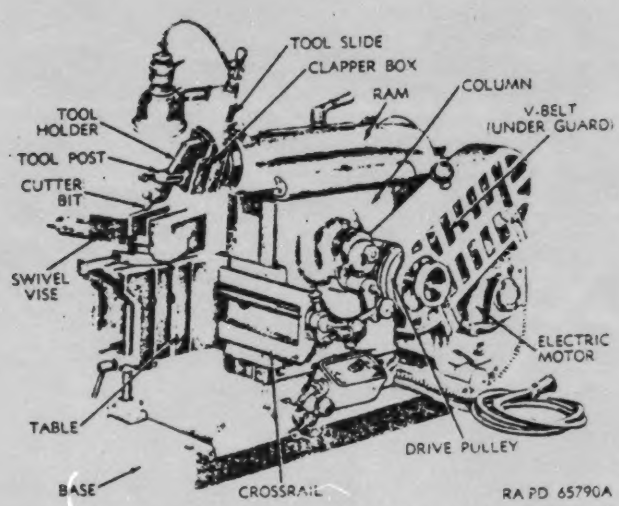


Figure 2. Bench-mounted horizontal metal cutting shaper.

b. Types of shaper cutter bits. In general, shaper cutter bits are identified as roughing or finishing tools. Finishing cutter bits usually contain sharp corners so that the tool can be fed into the angles of dovetails or used to finish the inside angles of shoulders where a radius or fillet is not desired. These finishing cutter bits are not suitable for the heavy cutting required of roughing cutter bits because their sharp cutting radii will dull or break off easily. Roughing cutter bits have rounded corners to distribute the force of the cut over a wider area, and can therefore be used with heavy feeds and deep cuts.

(1) Roundnose roughing cutter bit. The roundnose roughing cutter bit (fig 3) is used for general purpose roughing cuts with either right-hand or left-hand feed. This cutter bit usually contains no back rake or side rake. The roundnose roughing cutter bit is used mostly for light roughing on cast iron workpieces. A narrow roundnose roughing cutter bit (fig 4) is often used for miscellaneous roughing operations on small workpieces and for groove cutting.

(2) Left- and right-hand roughing cutter bits.

(a) The left-hand roughing cutter bit (fig 3) is used for the majority of roughing operations on cast iron and steel workpieces. This cutter bit is capable of heavy feeds and deep cuts. The cutter bit is supported vertically in the cutting toolholder for surface cuts and is offset at an angle for down cutting operations. No back rake is given to the left-hand roughing cutter bit, but the side rake may be as great as 15° or 20° for soft metals so that the heavy chip produced will curl and break at short intervals.

(b) The right-hand roughing cutter bit (fig 4) is ground like the left-hand roughing cutter bit ((a) above) only in reverse. This cutter bit is intended for roughing cuts from left to right when the normal right-to-left cutting procedure is impractical.

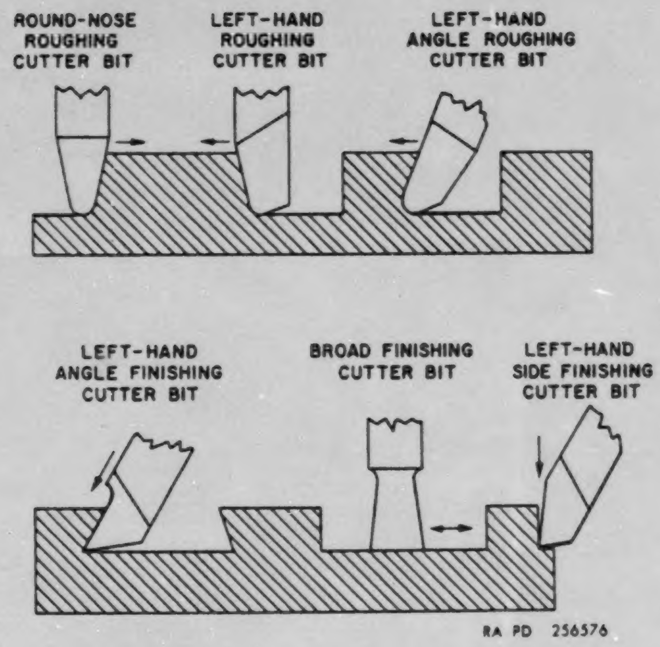

ROUND-NOSE ROUGHING CUTTER BIT
LEFT-HAND ROUGHING CUTTER BIT
LEFT-HAND ANGLE ROUGHING CUTTER BIT
LEFT-HAND ANGLE FINISHING CUTTER BIT
BROAD FINISHING CUTTER BIT
LEFT-HAND SIDE FINISHING CUTTER BIT
RA PD 256576

Figure 3. Shaper and planer cutter bits.

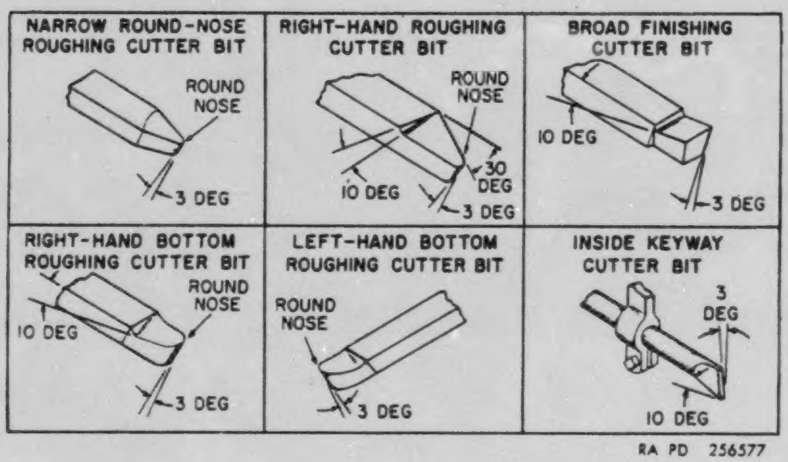

NARROW ROUND-NOSE ROUGHING CUTTER BIT
ROUND NOSE
3 DEG
RIGHT-HAND ROUGHING CUTTER BIT
ROUND NOSE
30 DEG
10 DEG
3 DEG
BROAD FINISHING CUTTER BIT
10 DEG
3 DEG
RIGHT-HAND BOTTOM ROUGHING CUTTER BIT
ROUND NOSE
10 DEG
3 DEG
LEFT-HAND BOTTOM ROUGHING CUTTER BIT
ROUND NOSE
3 DEG
INSIDE KEYWAY CUTTER BIT
3 DEG
10 DEG
RA PD 256577

Figure 4. Shaper cutter bits.

(3) Left- and right-hand bottom roughing cutter bits.

(a) The left-hand bottom roughing cutter bit (fig 4) is similar to the roundnose roughing cutter bit ((1) above) in shape, but is ground with about 10° of positive back rake and with varying amounts of side rake to direct the chips away from the workpiece surface. This cutter bit is designed primarily for very heavy roughing operations on machine steel workpieces.

(b) The right-hand bottom roughing cutter bit (fig 4) is ground like the left-hand bottom roughing cutter bit ((a) above) only in reverse. This cutter bit is used in place of the left-hand bottom roughing cutter bit when left-to-right feed is desired.

(4) Angle roughing cutter bit (fig 3). The left- and right-hand angle roughing cutter bits are used to rough cut dovetails and similar conformations where the cutter bit must be fed into the workpiece at an angle. The left-hand tool cuts to the left and the right-hand tool cuts to the right. In the machining of dovetails, the shape is roughed out with this tool and followed with a left- or right-hand angle finishing cutter bit ((7) below).

(5) Broad finishing cutter bit (fig 3 and 4). The broad finishing cutter bit has a flat tip and slightly recessed sides to provide necessary clearance. This cutter bit is used to finish flat surfaces, usually being operated with a shallow depth of cut and a heavy feed. The broad finishing cutter bit is well suited for finishing the bottom and sides of shoulder cuts, keyways, and wide grooves.

(6) Side finishing cutter bit (fig 3). The side finishing cutter bit may be either right-hand or left-hand and is used for finishing vertical cuts. Since this cutter bit has two cutting edges, small horizontal shoulders or surfaces may be finished with this cutter bit in order to avoid changing tools.

(7) Angle finishing cutter bit (fig 3). The angle finishing cutter bit is supplied in both right-hand and left-hand types and is used to finish dovetails or other similar shapes after roughing. Usually the tool is first fed laterally to finish the bottom of the cut, and then fed downward at an angle to finish the angular side of the cut.

(8) Inside keyway cutter bit (fig 4). The inside keyway cutter bit differs basically from the cutter bits described above in that it is formed from a round shank rather than a square shank. Mounted in an appropriate cutting toolholder, this cutter bit may be used for cutting keyways and splines in workpiece bores. This cutter bit can be ground to various widths.

c. Clearance and rake angles. The nomenclature used for shaper cutter bits is the same as that for lathe cutter bits, and the elements of the cutter bit, such as clearance and rake angles, are in the same relative positions as shown in figure 5.

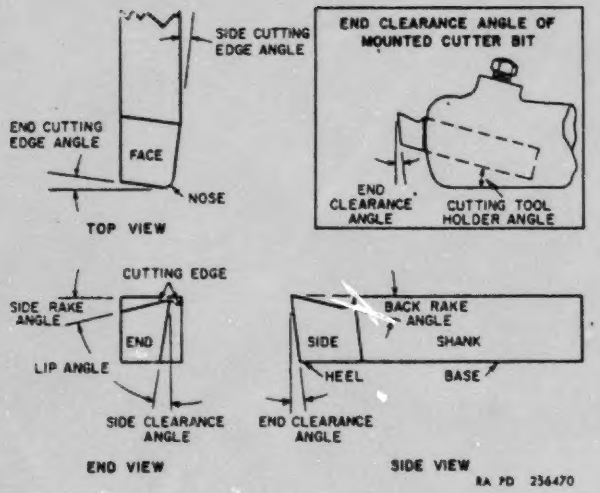

SIDE CUTTING EDGE ANGLE
END CUTTING EDGE ANGLE
FACE
NOSE
TOP VIEW
END CLEARANCE ANGLE OF MOUNTED CUTTER BIT
END CLEARANCE ANGLE
CUTTING TOOL HOLDER ANGLE
CUTTING EDGE
SIDE RAKE ANGLE
END
LIP ANGLE
SIDE CLEARANCE ANGLE
END VIEW
BACK RAKE ANGLE
SIDE
SHANK
HEEL
BASE
END CLEARANCE ANGLE
SIDE VIEW
RA PD 236470

Figure 5. Terms applied to single-point cutter bits.

(1) Less end clearance (clearance at the heel of the cutter bit) is required for shaper cutter bits than for lathe cutter bits.

(2) Cutter bits designed for roughing operations with the shaper are often ground without back rake and with a large side rake angle. This design generally reduces the tendency of the cutter bit to chatter.

(3) Table I lists clearance and rake angles commonly used for the machining of different materials with the shaper.

TABLE I. CLEARANCE AND RAKE ANGLES FOR SHAPER AND PLANER CUTTER BITS

Material	Operation	Side clearance angle (deg.)	End clearance angle (deg.)	Back rake angle (deg.)	Side rake angle (deg.)
Aluminum	Roughing	5-9	2-5	2-8	16-22
	Finishing	0	2-5	8	16-22
Brass	Roughing	5-9	2-5	2-8	4-10
	Finishing	0	2-5	14-22	0
Bronze	Roughing	5-9	2-5	2-8	4-10
	Finishing	0	2-5	14-22	0
Cast iron	Roughing	5-9	2-5	2-8	14
	Finishing	0	2-5	6-10	0
Copper	Roughing	5-9	2-5	2-10	16-20
	Finishing	0	2-5	8	16-20
Magnesium	Roughing	6-10	2-5	0-5	3-5
	Finishing	0	2-5	10-15	0
Monel metal	Roughing	5-9	2-5	0-4	10-14
	Finishing	0	2-5	14-22	0
Steel, hard	Roughing	5-9	2-5	0-6	10-14
	Finishing	0	2-5	8-14	0
Steel, soft	Roughing	5-9	2-5	0-8	14-22
	Finishing	0	2-5	14-22	0
Steel, very hard	Roughing	5-9	2-5	0-5	5-10
	Finishing	0	2-5	5-10	0

d. Grinding of shaper cutter bits. As with all cutting tools used for machining, shaper cutter bits should be kept sharp for efficiency of operation and quality of machined surfaces. A dull cutter bit overworks the machine tool, cuts slowly, and produces a poor finish. Shaper cutter bits are ground off-hand on utility grinding machines. It should be remembered that high-speed steel cutter bits must be ground dry; dipping these tools in water when hot will crack the cutting edge. After grinding, the cutting edge of the cutter bit should be carefully honed with an oilstone to produce a smooth edge. This practice will increase the life of the cutting edge as well as making possible a smoother cut.

e. Mounting of shaper cutter bits. Cutter bits for shapers are usually mounted in cutting toolholders which are secured to a toolpost (fig 2) on the clapper block of the machine. The cutting toolholders are made in different shapes, some designed to support the cutter bit at an offset angle, and others designed to hold the cutter bit at a variety of different angles.

5. CUTTING TOOLHOLDERS.

a. General.

(1) Various types of cutting toolholders are available for securing shaper cutter bits to the machine tool. These cutting toolholders are usually forged steel bars containing an opening into which the cutter bit is positioned and locked in place by means of a setscrew or bolt.

(2) The cutting toolholder mounts to the toolpost (fig 2) projecting forward from the shaper clapper block.

(3) The common types of cutting toolholders for shaper use are the straight shank cutting toolholder, the right- and left-hand offset cutting toolholders, the swivel head cutting toolholder (fig 6), and the extension bar cutting toolholder (fig 6).

b. Straight-shank cutting toolholder. The straight-shank cutting toolholder is similar to the straight-shank cutting toolholder used with the lathe, the major difference being that this cutting toolholder is larger and supports the cutter bit on a line parallel to the axis of the shank, while the similar lathe cutting toolholder supports the bit at an upward angle. The straight-shank cutting toolholder is supplied in different sizes, each intended for supporting one size of cutter bit.

c. Offset cutting toolholders. The offset cutting toolholders are supplied with right-hand or left-hand offset angles for supporting the cutter bit at an angle for different shaper operations. These toolholders differ from the right- and left-hand offset cutting toolholders used with the lathe in that they are generally larger and the cutter bit remains vertical although offset to the left or right. With the corresponding lathe toolholder, the cutter bit is offset vertically as well as laterally.

d. Swivel head cutting toolholder. The swivel head cutting holder (fig 6) is a popular toolholder because a cutter bit can be mounted in it in several different radial positions. This feature allows it to be used as a straight shank holder or a right-hand or left-hand offset holder and also permits mounting of the cutter bit at right angles to the shank.

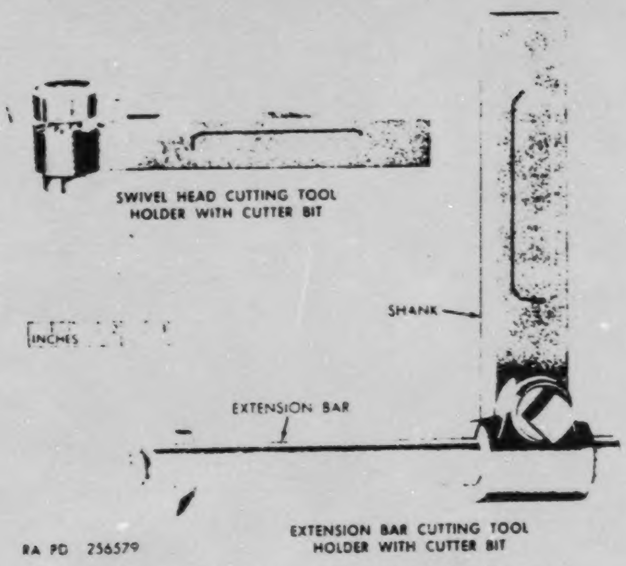

SWIVEL HEAD CUTTING TOOL HOLDER WITH CUTTER BIT
SHANK
INCHES
EXTENSION BAR
EXTENSION BAR CUTTING TOOL HOLDER WITH CUTTER BIT
RA PD 256579

Figure 6. Shaper cutting toolholders.

e. Extension bar cutting toolholder. The extension bar cutting toolholder (fig 6) supports the cutter bit in an extension bar projecting forward from the shank of the holder. This cutting toolholder is adapted for cutting internal splines and keyways on the shaper. The extension bar may be adjusted in the shank for length or for radial position by releasing a setscrew. The cutter bit fits through a slot in one end of the extension bar and is clamped in place by a setscrew.

6. SWIVEL VISE. The swivel vise is the most common machine tool attachment used with the shaper. It is essentially the same as the swivel vise used for holding workpieces to the milling machine table (fig 7) and usually attaches to the shaper table with T-slot bolts. The vise body can be swiveled 260° on a graduated base. The base is keyed to the shaper table to maintain alinement of the graduated scale.

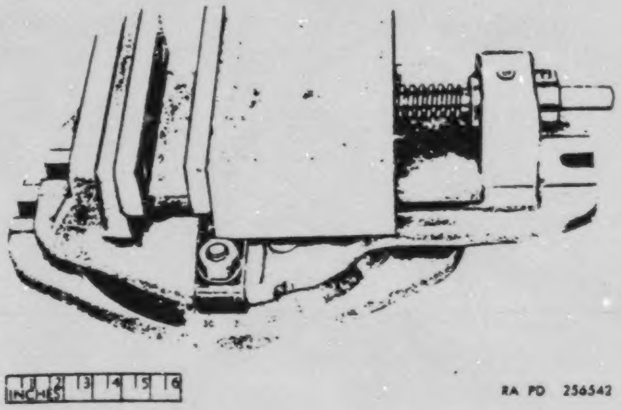

1 2 3 4 5 6
INCHES
RA PD 256542

Figure 7. Swivel vise.

7. SHAPER ROTARY TABLE. The shaper rotary table (fig 8) consists chiefly of a circular table containing T-slots, a table base, and an indexing pin. The circular table has an engraved graduated scale and 12 equally spaced index pinholes in the circumferential surface whereby the table can be fixed in any desired position of rotation. Workpieces are clamped to the circular tabletop, using T-bolts. Typical operations performed in conjunction with the shaper rotary table include slotting and angle cutting of workpieces which, due to their shape, cannot be mounted conveniently in the swivel vise.

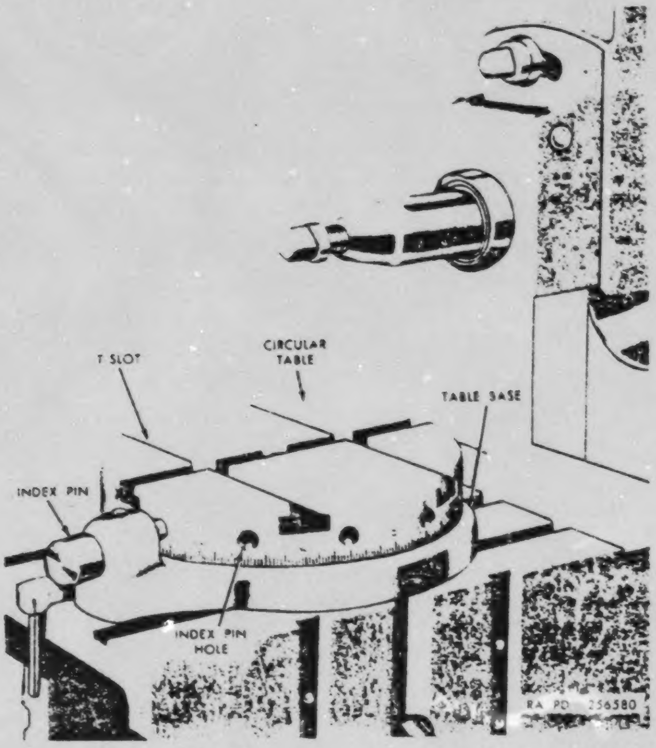


Figure 8. Shaper rotary table.

8. INDEXING FIXTURE.

a. General. An indexing fixture (fig 9) is provided as a machine tool attachment with some shapers to hold the index workpieces for keyway and spline cutting operations. The indexing fixture is generally much simpler than the indexing fixtures used with milling machines and the milling and grinding lathe attachment.

b. Construction. The shaper indexing fixture usually consists of a base, an index head, one or more indexing plates, and centers. The workpiece must be drilled and countersunk at each end so that it can be mounted between the live center in the index head and the dead center in the base. A clamp dog is used to lock the workpiece to the index head spindle. The indexing plate, containing equally spaced pinholes, is mounted to the forward end of the index head spindle where it contacts an indexing pin mounted at the side of the index head. Indexing is accomplished by moving the indexing plate a specified number of holes past the indexing pin to rotate the workpiece a desired distance. Unlike the indexing fixtures for the milling machine and milling and grinding lathe attachment, the indexing plates are coupled directly to the index head spindle. Indexing plates containing rings of different numbers of holes are furnished.

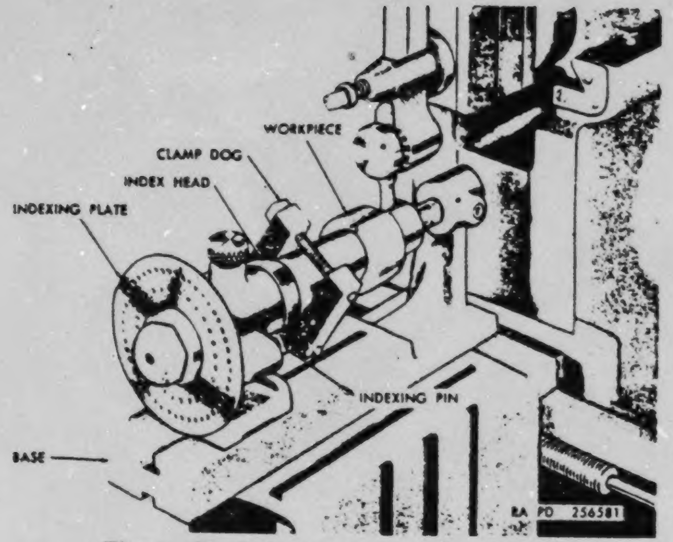

WORKPIECE
CLAMP DOG
INDEX HEAD
INDEXING PLATE
INDEXING PIN
BASE
RA PD 256581

Figure 9. Indexing fixture for the shaper.

9. MOUNTING WORKPIECES.

a. Side mounting. Cylindrical stock requiring end surfacing can be mounted to the side of some shaper tables. On these machines, a vertical V-groove is machined in the side of the shaper table, and cylindrical workpieces can be clamped in this groove by application of a simple strap secured by bolts to the table (fig 10).

b. Rotary mounting. Figure 11 shows a workpiece properly mounted to the shaper rotary table. Note that the workpiece in this case has been fastened to the table using T-slot bolts. The workpiece also can be clamped to the table using machine strap clamps with the T-slot bolts, or an angle plate can be fastened to the table and the workpiece clamped to the angle plate.

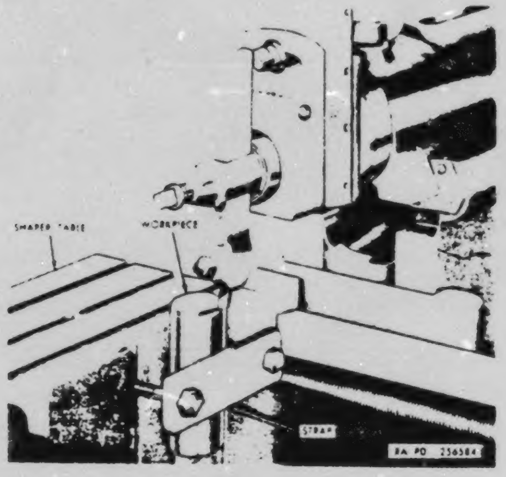

SHAPER TABLE
WORKPIECE
STRAP
RA PD 256584

Figure 10. Mounting cylindrical stock to side of the shaper table.

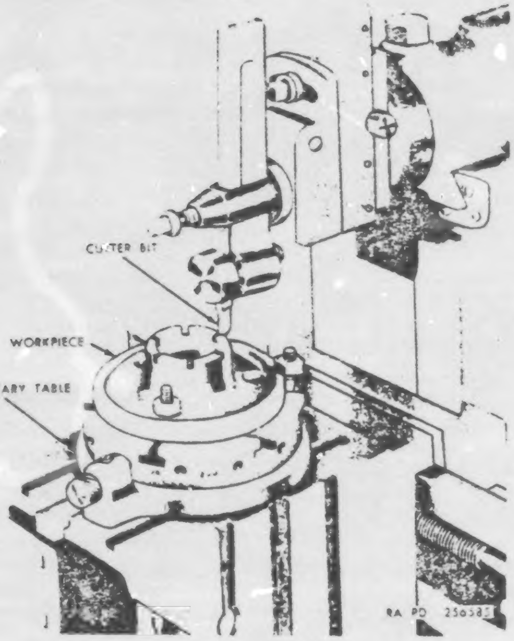


Figure 11. Slotting operation with workpiece mounted on shaper rotary table.

10. SHAPER CUTTING SPEEDS.

a. General. Shaper cutting speed is designated as the rate in feet per minute the cutting tool passes over the workpiece. This rate applies only to the cutting stroke and not to the return stroke.

b. Factors governing speed. The correct speed to be used for any given shaper operation will depend on the size, shape, and material of the cutter bit or cutting tool, the type of material to be cut, the cutting oil used (if any), the feed and depth of cut selected, and the speed limitations of the particular shaper.

c. Selection of cutting speeds. Typical cutting speeds for various materials are listed in table II. These speeds are approximate and should be readjusted if excessive tool wear is noted.

TABLE II. SHAPER CUTTING SPEEDS

Material	Operation[1]	Cutting speed for high-speed steel cutter bits (fpm)
Aluminum	Roughing and finishing	60 to 200
Brass	Roughing and finishing	50 to 100
Bronze	Roughing and finishing	30 to 80
Cast iron	Roughing...............	35 to 70
	Finishing.............	25 to 45
Copper	Roughing and finishing	30 to 80
Monel metal	Roughing and finishing	30 to 50
Steel, machine	Roughing and finishing	45 to 75
Steel, hard	Roughing and finishing	25 to 60
Steel castings	Roughing and finishing	30 to 60
Steel forgings:		
Soft	Roughing and finishing	40 to 60
Hard alloys	Roughing and finishing	12 to 30

[1] Except for cast iron, metals are roughed and finished at the same speed. However, when broad cutting tools are used with wide feeds for finishing large surfaces, a slower cutting speed is used to conserve the cutting tool.

11. SETTING SHAPER STROKE.

a. General. Knowledge of proper cutting speeds for the shaper is valueless without understanding the reciprocating action of the shaper ram and how cutting speeds are translated into strokes per minute of the ram.

b. Changing cutting speed to strokes per minute. The ram of the shaper reciprocates, or moves forward and back, to push the cutter bit across the workpiece and pull the cutter bit back again. The cutter bit cuts only on the forward movement, and this is designated as the cutting stroke. The back movement of the ram, during which the cutter bit does not cut, is called the return stroke.

(1) On all shapers, the return stroke is quicker than the cutting stroke. On most shapers, the ratio of the time of the cutting stroke to the return stroke in any one cycle is 3 to 2; or, in other words, the cutting stroke consumes three-fifths of the cycle time and the return stroke consumes two-fifths of the time.

(2) To change a cutting speed given in feet per minute to cutting strokes per minute, it is necessary to apply a formula based on the relationship of the cutting stroke time to the return stroke time ((1) above). The formula is: Number of strokes per minute equals the cutting speed in f.p.m. (feet per minute) divided by the product of 0.14 times the length of the stroke in inches, or:

$$\text{Number of strokes per minute} = \frac{\text{cutting speed (f.p.m.)}}{0.14 \times \text{stroke length (inches)}}$$

For example, if it is desired to cut material at 70 feet per minute cutting speed, and the shaper ram is adjusted for a 5-inch stroke, the number of strokes per minute equals 70 divided by the product of 5 times 0.14, or 70 divided by 0.7 or 100 strokes per minute.

(3) If the number of strokes per minute and the length of the stroke is known and it is desired to calculate the cutting speed, multiply the number of strokes per minute by the length of the stroke in inches, and then multiply the product by 0.14, as: cutting speed (f.p.m.) = 0.14 x stroke length (in.) x number of strokes per minute. For example, if the shaper makes 100 strokes per minute, and the stroke is 5 inches long, the cutting speed equals 0.14 times 5 times 100, or 70 feet per minute.

c. Adjusting length of stroke.

(1) Since the length of the shaper stroke is a factor relating the cutting speed in feet per minute to the shaper ram speed in strokes per minute, it can be seen that excessive travel of the ram during each stroke will increase the time required to complete a job. For example, if a workpiece is 4 inches long and the stroke of the machine is adjusted to 10 inches, it will take twice as long to machine the workpiece at a given cutting speed than it will if the stroke were adjusted to 5 inches.

(2) For economical operation of the shaper, the stroke should be adjusted to equal the length of the workpiece plus an additional 5/8 inch for clearance. The 5/8-inch clearance addition applies to most common shaper operations. Some specific operations will require a greater or lesser clearance.

d. Positioning the stroke. After the stroke is adjusted to the proper length, it is necessary to position the ram so that the stroke is located over the workpiece as illustrated in figure 12. The ram should be positioned so that the cutter bit moves 1/4 inch beyond the workpiece on the forward or cutting stroke, and 3/8 inch behind the workpiece on the return stroke. When positioning the stroke, the ram should be moved throughout a complete cycle by hand to make sure the ram was located at the extreme end of the stroke when the adjustment was made.

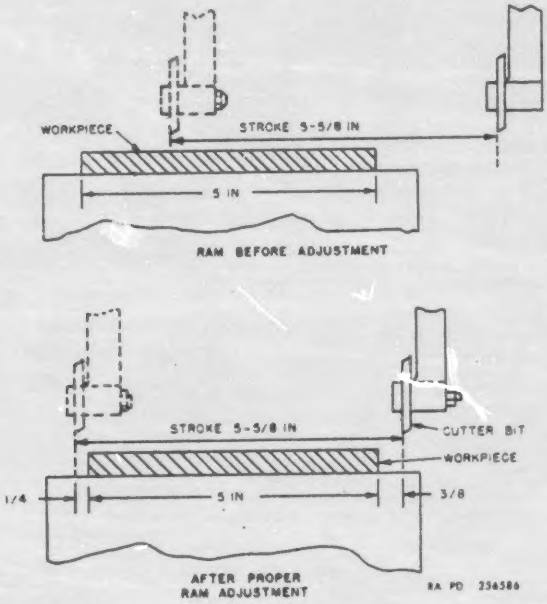


Figure 12. Locating ram stroke position.

12. HORIZONTAL PLANING.

a. General. Much of the work done on the shaper is the planing of flat surfaces on workpieces. The horizontal surface produced is the result of a series of cuts made with a single-point cutter bit.

b. Setting up workpiece. The workpiece to be horizontally planed is mounted in the swivel vise, mounted on the shaper rotary table, or mounted directly to the table of the shaper. The shaper should be properly alined and the surface to be planed should be adjusted parallel to the table. The workpiece must be rigidly mounted to prevent possible shifting that would result in an inaccurate cut.

c. Horizontal planing operation. Wherever possible, the cut is made from the right side of the workpiece to the left so that the operator can easily observe the cutting action from his position at the right side of the machine. In this case, a left-hand cutter bit is used. The table is fed to the right. An example of horizontal planing is shown in figure 13.

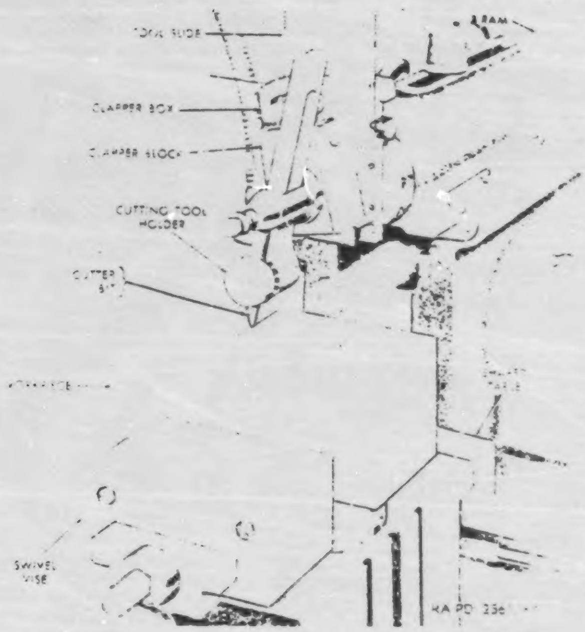


Figure 13. Horizontal planing operation.

13. ANGULAR PLANING.

a. General. Angular planing is the cutting of a surface on the shaper which is neither parallel nor perpendicular to the surface of the shaper worktable. This operation should not be confused with the cutting of angular surfaces by horizontal planing, with the workpiece mounted at an angle to the shaper table.

b. Setting up workpiece. The workpiece should be mounted in the swivel vise or directly to the shaper table. Clearance for the cutting toolholder and cutter bit must be taken into consideration if the angular surface is to be cut across one edge of the workpiece. This may necessitate mounting the workpiece higher than usual in the vise on parallels, or it may dictate a special arrangement of clamping devices if the workpiece is to be mounted directly to the shaper table.

c. Angular planing operation. Angular planing is performed in the same basic manner as vertical planing using the tool slide to feed the cutter bit across the workpiece surface. The angular movement, however, is achieved by rotating the toolhead on the ram to set the tool slide parallel to the surface to be cut (fig 14). Using the engraved scale on the ram, the toolhead is set to the complement of the angle to be cut (90° minus the angle to be cut).

14. SLOTTING.

a. General. Slotting operations are performed with inside keyway cutter bits having clearance angles ground on both sides. The cutter bit is fed downward into the workpiece using the tool slide. Typical slotting operations for shapers include keyway planing and spline cutting.

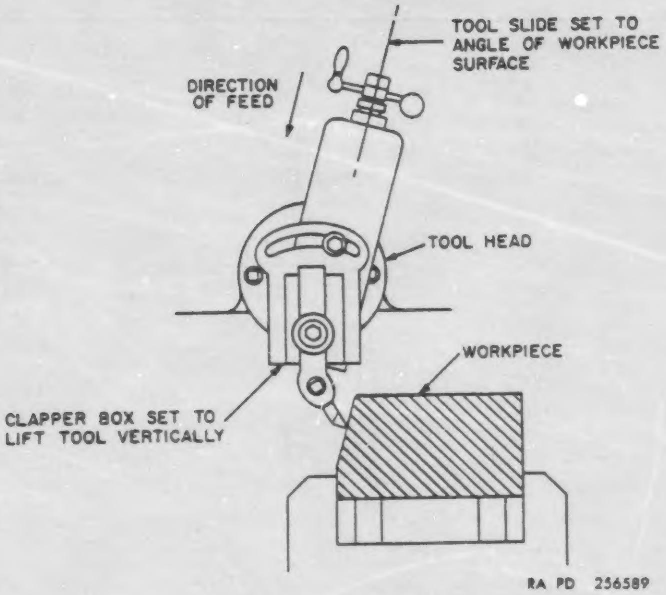

TOOL SLIDE SET TO ANGLE OF WORKPIECE SURFACE
DIRECTION OF FEED
TOOL HEAD
WORKPIECE
CLAPPER BOX SET TO LIFT TOOL VERTICALLY
RA PD 256589

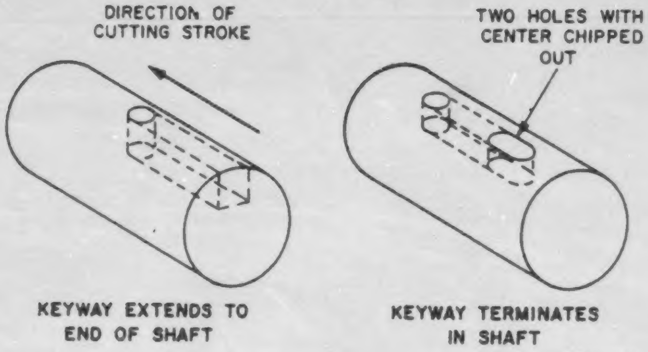
Figure 14. Angular planing operation.

b. Setting up workpiece.

(1) The workpiece can be vise mounted or mounted directly to the shaper table if the slot is to be cut in the surface of flat stock. For slotting operations requiring indexing of slots, the workpiece should be set up on the shaper rotary table or in the indexing fixture.

(2) When planing keyways that do not run the full length of the shaft, a hole must be drilled at the point where the cut will terminate. This hole (fig 15) must be on the same width and depth as the keyway. It is drilled to prevent building up chips in front of the cutter bit, thereby allowing the keyway to be cut to full size throughout its depth.

(3) Where the finished keyway will not extend to either end of the shaft, starting holes must be drilled at both ends of the keyway (fig 15). Usually two adjacent holes are drilled at the starting point and the metal between the holes chipped out to give the cutter bit clearance to start the cut. This practice also provides sufficient clearance at the start of the cut for the cutter bit to drop back down into position for the next cut.


DIRECTION OF CUTTING STROKE
TWO HOLES WITH CENTER CHIPPED OUT
KEYWAY EXTENDS TO END OF SHAFT
KEYWAY TERMINATES IN SHAFT

RA PD 256590

Figure 15. Starting holes for keyway cutting.

15. INTERNAL SLOTTING.

a. General. Internal slotting is the operation of cutting slots in restricted areas of workpieces where a normal toolholder cannot enter, such as the cutting of keyways or internal splines in a bore. This operation is performed using an extension bar cutting toolholder to permit entry of the cutter bit in the bore.

b. Setting up workpiece. The workpiece is mounted either directly to the shaper table or in the swivel vise. The workpiece must be firmly mounted and the vise jaws or clamping devices must not be positioned where interference to the toolholder or cutter bit may result. It is suggested that a radial line be scribed on the hub to assist in alining the cutter bit with the workpiece.

(1) The extension bar of the extension bar cutting toolholder (fig 6) should project forward from the toolholder shank only as far as required to permit the cutter bit to complete its cutting stroke. Excessive projection of the extension bar will increase the tendency for the cutter bit to chatter.

(2) After setting and positioning the shaper stroke, move the ram by hand through one cycle to determine that all clearances are sufficient. Particular attention should be given to the rear of the extension bar which might strike the shaper column if improperly positioned.

(3) The clapper box and the tool slide must both be positioned vertically to prevent binding of the cutter bit during the return stroke.

c. Internal slotting operation. A typical internal slotting operation is shown in figure 16.

16. PLANING IRREGULAR SURFACES.

a. Irregular surfaces are often planed on the shaper using either hand crossfeed and hand downfeed or using automatic table crossfeed and hand downfeed. In either case, the planing operation is one requiring constant attention of the operator and a fair degree of skill on his part.

Figure 16. Internal slotting operation.

b. The planing operation consists of a series of horizontal roughing cuts, the cutter bit and the workpiece being manipulated until the metal is cut to within 1/16 inch of the layout line.

c. A roundnose cutter bit is used to make two finishing cuts, each cut removing 1/32 inch of metal. It is recommended that final finishing of the surface be performed by hand filing to eliminate possible tearing of the edges caused by breaking of chips.

17. SUMMARY. The development, improvements, purpose, and operation of shapers were discussed in this lesson. You also received information on the types of shapers and shaper cutting tools. You learned the procedures for mounting workpieces, how to set speeds and strokes, and were oriented on planing and slotting operations. As a result of this lesson, your knowledge of shaper operations should be enhanced.

EXERCISE

91. What designates the size of a shaper?

- a. Distance from the base to the tool slide
- b. Width and length of shaper table
- c. Maximum length of ram stroke

92. What permits lateral and vertical movement of the shaper table?

- a. Crossrail
- b. Motor
- c. Indexing fixture

93. Why are vertically supported roughing cutter bits offset?

   a. Allow down cutting
   b. Provide right-hand cutting
   c. Provide left-hand cutting

94. In which direction would a left-hand side finishing cutter bit normally move when cutting?

   a. Backward
   b. Forward
   c. Down

95. A cutter bit with a side clearance angle of 5° to 9°, a back rake angle of 2° to 8°, and a rake angle of 4° to 10° would be suitable for roughing what type of metal?

   a. Cast iron
   b. Brass
   c. Copper

96. What is the proper shaper cutting speed when using high speed steel cutting bits for roughing and finishing aluminum?

   a. 30 to 80 FPM
   b. 45 to 75 FPM
   c. 60 to 200 FPM

97. If a shaper makes 70 strokes a minute and the stroke is 5 inches long, what is the cutting speed in feet per minute?

   a. 84
   b. 49
   c. 45

98. When planing a 17° angle on an angular piece of stock, what should be the degree reading on the toolhead?

   a. -17
   b. 83
   c. 73

99. What is used to fasten workpieces to the shaper rotary table?

   a. Tee-head bolt
   b. Hexagon head screw
   c. C-clamp

100. How far should the extension bar of the extension bar cutting toolholder project be forward from the toolholder shank when cutting an internal keyway?

   a. Never more than 3/8 inch behind the workpiece
   b. Only as far as required to prevent chatter
   c. As far as required to complete the cutting stroke

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 424	Machine Shop Practice
Lesson 7	Milling Machine
Credit Hours	Two
Lesson Objective	After studying this lesson you will be able to: 1. Discuss milling machines as to history, types, use, nomenclature, and operation. 2. Discuss milling machine accessory components as to types, use, selection, mountings, care, and maintenance. 3. Explain various milling machine functions to include indexing workpieces, setting rate of speed and feed, plain milling, angular milling, straddle milling, gang milling, face milling, form milling, drilling, and milling woodruff keyways.
Text	Attached Memorandum
Materials Required	None
Suggestions	If possible, visit a machine shop and observe the methods used in milling machine operations.

STUDY GUIDE AND ATTACHED MEMORANDUM

1. INTRODUCTION.

a. History. The first milling machine was invented in America in 1818 by Eli Whitney, the inventor of the cotton gin. This machine (fig 1) was developed to mass-produce interchangeable musket parts. He found that accuracy and uniformity could not be maintained using the old system of hand filing on filing jigs because the jigs were subjected to wear when the file touched the jig control surfaces, and only a few parts could therefore be accurately filed before the jig was inaccurate. The milling machine Whitney developed had a horizontal spindle to which disks containing cutter teeth in the rim could be mounted and rotated. A sliding table was devised by which the workpiece could be moved beneath the rotating disk. On Whitney's machine, the table feed was powered by a belt connecting a feed shaft with the milling machine spindle.

b. Developments. Later developments in milling machines were made by Robbins and Laurence in 1853 and by Brown and Sharpe Manufacturing Company in 1855. The Brown and Sharpe machine was used primarily for cutting spur gears. In 1861, Brown and Sharpe constructed the first universal milling machine which resembles the knee-type universal milling machines of today. This machine contained an indexing head and a variable speed table feed driven off the milling machine spindle. Its first important uses were the cutting of grooves in twist drills and the making of musket parts during the Civil War.

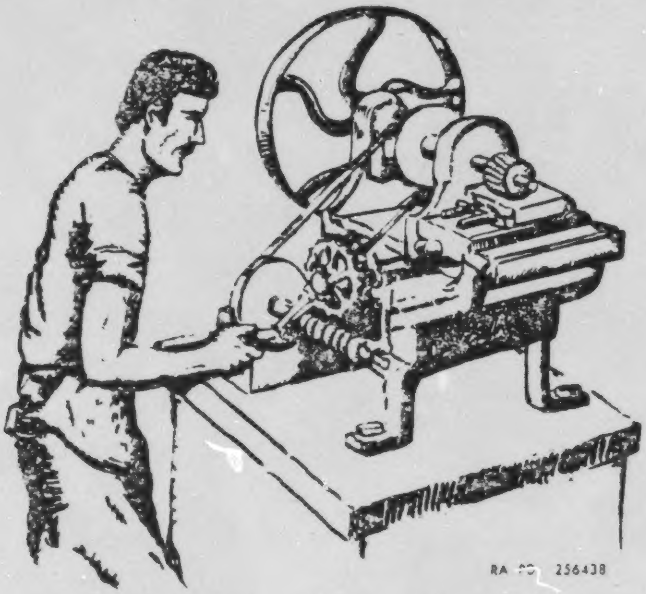


Figure 1. Whitney's milling machine—1818.

c. Improvements. By 1915, the milling machine had been developed to such a degree that the machine was capable of doing much heavier work than the milling cutters that had been previously developed. Heavier arbors were substituted, and new cutters shaped more like drums than disks were developed so that more material could be removed from workpieces in one pass of the table. High-speed tool steel had been developed in 1898 and permitted fast cuts to be taken with these new cutters. Helical cutting teeth and staggered teeth were later developed to reduce the tendency of the tool to chatter while cutting. Variations of the milling machine were later developed to perform special milling operations. Among these machines are the vertical milling machine, the ram-type milling machine, and the profiling machine.

2. GENERAL.

a. Purpose. Milling is the process of machining flat, curved, or irregular surfaces by feeding the workpiece against a rotating cutter containing a number of cutting edges. The process is identical in method to circular sawing; it is exactly opposed in method to lathe turning where the workpiece rotates against a stationary cutter bit.

b. Construction. The milling machine consists basically of a motor driven spindle, which mounts and revolves the milling cutter, and a reciprocating adjustable worktable, which mounts and feeds the workpiece past the milling cutter.

c. Uses. It is not possible to list every operation with the capabilities of the milling machine. The milling machine is excellent for forming flat surfaces, cutting dovetails and keyways, forming and fluting milling cutters and reamers, cutting gears, and so forth. Many special operations can be performed with the attachments available for milling machine use.

3. TYPES OF MILLING MACHINES.

a. General. Milling machines are basically classified as being horizontal or vertical to indicate the axis of the milling machine spindle. These machines are also classified as being knee-type milling machines, ram-type milling machines, manufacturing or bed-type milling machines, and planer-type milling machines. Most milling machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power-operated table feeds.

b. Knee-type milling machines.

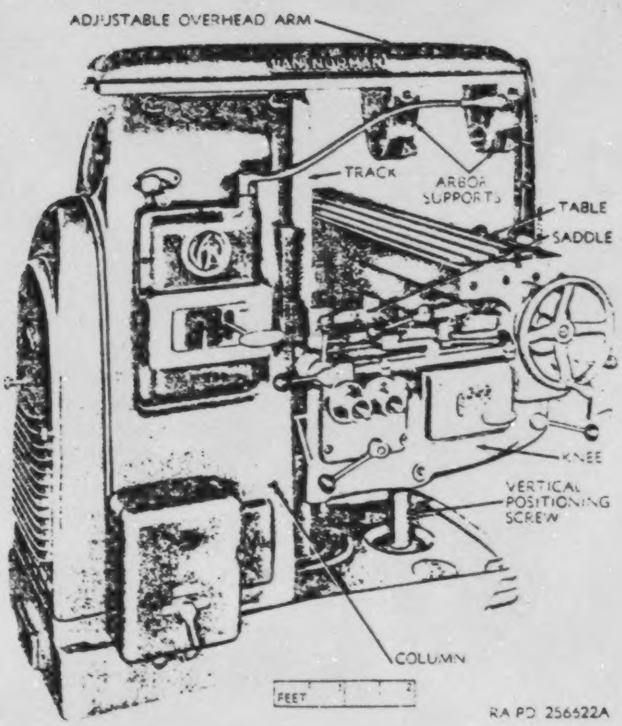
(1) Description. Knee-type milling machines are characterized by a vertically adjustable worktable resting on a saddle that is supported by a knee. The knee is a massive casting that rides vertically on the milling machine column and can be clamped rigidly to the column in a position where the milling head and milling machine spindle are properly adjusted vertically for operation. Of the knee-type class of milling machines, the most popular machines are the plain horizontal milling machine and the universal horizontal milling machine.

(2) Floor-mounted plain horizontal milling machine (fig 2).

(a) The floor-mounted plain horizontal milling machine's column contains the drive motor and gearing and a fixed-position horizontal milling machine spindle. An adjustable overhead arm containing one or more arbor supports projects forward from the top of the column. The arm and arbor supports are used to stabilize long arbors upon which the milling cutters are fixed. The arbor supports can be moved along the overhead arm to support the arbor where support is desired depending on the position of the milling cutter or cutters.

(b) The knee of the machine rides up or down the column on a rigid track. A heavy, vertical positioning screw beneath the knee is used for raising and lowering. The saddle rests upon the knee and supports the worktable. The saddle moves in and out on a dovetail to control crossfeed of the worktable. The worktable traverses to the right or left upon the saddle for feeding the workpiece past the milling cutter. The table may be manually controlled or power fed.

(3) Bench-type plain horizontal milling machine (fig 3). The bench-type plain horizontal milling machine is a small version of the machine described in (2) above, being mounted to a bench or a pedestal instead of directly to the floor. The milling machine spindle is horizontal and fixed in position. An adjustable overhead arm and arbor support are provided. The worktable is generally not power fed on this type machine. The saddle slides on a dovetail on the knee providing crossfeed adjustment. The knee moves vertically up or down the column to position the worktable in relation to the spindle.


ADJUSTABLE OVERHEAD ARM
TRACK
ARBOR SUPPORTS
TABLE
SADDLE
KNEE
VERTICAL POSITIONING SCREW
COLUMN
FEET

RA PD 256522A

Figure 2. Knee-type floor-mounted plain horizontal milling machine.

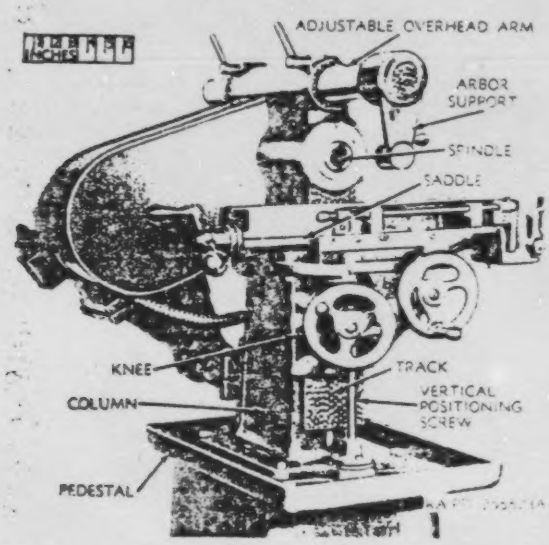

INCHES
ADJUSTABLE OVERHEAD ARM
ARBOR SUPPORT
SPINDLE
SADDLE
KNEE
TRACK
COLUMN
VERTICAL POSITIONING SCREW
PEDESTAL

Figure 3. Bench-type plain horizontal milling machine.

(4) Floor-mounted universal horizontal milling machine (fig 4).

(a) The basic difference between a universal horizontal milling machine and a plain horizontal milling machine is in the adjustment of the worktable and the number of attachments and accessories available for performing various special milling operations. The universal horizontal milling machine has a worktable that can swivel on the saddle with respect to the axis of the milling machine spindle, permitting workpieces to be adjusted in any position in relation to the milling cutter or cutters. The universal machine is always supplied with attachments such as the indexing fixture.

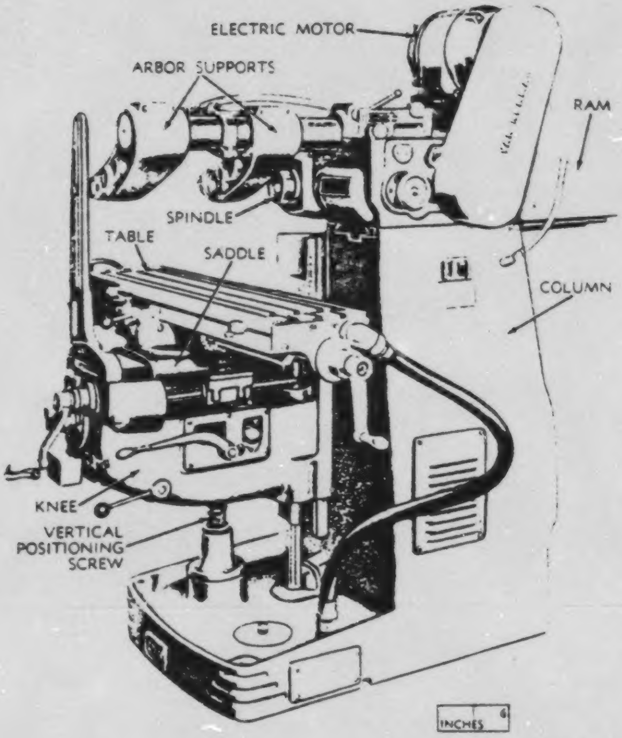


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Figure 4. Floor-mounted universal horizontal milling machine.

(b) The universal horizontal milling machine illustrated in figure 4 also differs from the plain horizontal milling machine in figure 2 in that it is of the ram type; the milling machine spindle is mounted in a ram at the top of the column that can be moved in and out to provide crossfeed for milling operations. This feature permits additional rigidity of the worktable since a crossfeed dovetail is not necessary between the knee and the saddle.

c. Ram-type milling machines.

(1) Description. The ram-type milling machine is characterized by a spindle mounted to a movable housing on the column to permit feeding the milling cutter forward or rearward in a horizontal plane. Two popular ram-type milling machines are the floor-mounted universal milling machine and the swivel cutter head ram-type milling machine.

(2) Swivel cutter head ram-type milling machine (fig 5). This milling machine can be classified as a universal milling machine. A cutter head containing the milling machine spindle is attached to the ram. The cutter head can be swiveled from a vertical spindle position to a horizontal spindle position or can be fixed at any desired angular position between vertical and horizontal. The saddle and knee are hand driven for vertical and crossfeed adjustment while the worktable can be either hand driven or power driven at the operator's choice.

4. MILLING CUTTERS.

a. Classification of milling cutters.

(1) General. Milling is the process of removing metal by means of a rotating cutting tool or tools having a number of cutting edges called teeth. Such tools are known as milling cutters or mills. They are usually made of high-speed steel and are available in a great variety of shapes and sizes for various purposes. (There are over 50 kinds of cutters in general use; over 4,000 stock sizes.) The names of the most common classifications of cutters, their uses, and, in a general way, the sizes best suited to the work in hand are described in some detail in paragraphs below.

(2) Milling cutter nomenclature. Figure 6 shows two views of a common milling cutter with its parts and angles identified. These parts and angles in some form are common to all types of cutters.

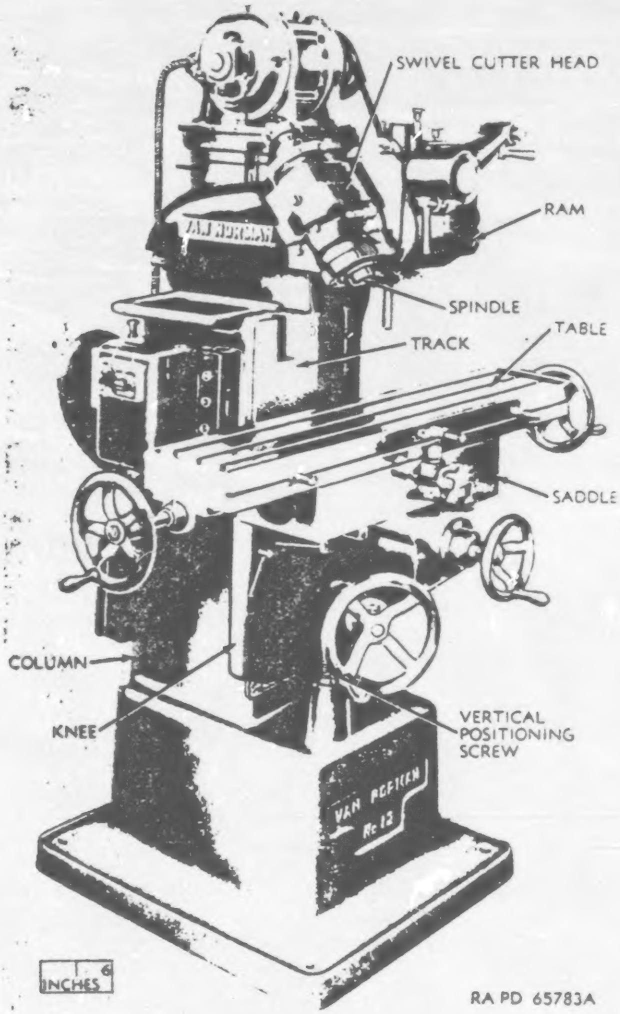
(a) Pitch. The pitch refers to the angular distance between like parts on adjacent teeth. The pitch is determined by the number of teeth.

(b) Face of tooth. The tooth face is the forward facing surface of the tooth that forms the cutting edge.

(c) Land. The land is the narrow surface behind the cutting edge on each tooth.

(d) Cutting edge. The cutting edge is the angle on each tooth that performs the cutting.

(e) Rake angle. The rake angle is the angle formed between the face of the tooth and the center line of the cutter. The rake angle defines the cutting edge and provides a path for chips that are cut from the workpiece.


SWIVEL CUTTER HEAD
RAM
SPINDLE
TABLE
TRACK
SADDLE
COLUMN
KNEE
VERTICAL POSITIONING SCREW
VAN NORMAN
VAN NORMAN No 12
INCHES
6

RA PD 65783A

Figure 5. Swivel cutter head ram-type milling machine.

(f) Primary clearance angle. The primary clearance angle is the angle of the land of each tooth measured from a line tangent to the centerline of the cutter at the cutting edge. This angle prevents each tooth from rubbing against the workpiece after it makes its cut.

(g) Secondary clearance angle. This angle defines the land of each tooth and provides additional clearance for passage of cutting oil and chips.

(h) Hole diameter. The hole diameter determines the size arbor necessary to mount the milling cutter.

(i) Keyway. A keyway is present on all arbor-mounting cutters for locking the cutter to the arbor.

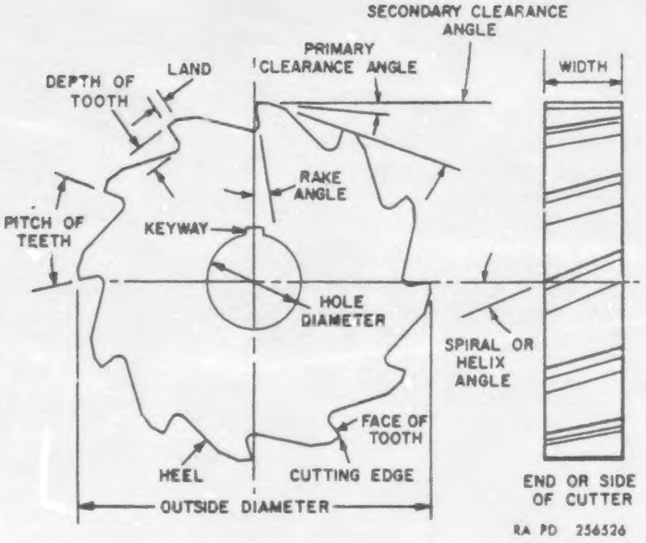

SECONDARY CLEARANCE ANGLE
PRIMARY CLEARANCE ANGLE
LAND
DEPTH OF TOOTH
WIDTH
RAKE ANGLE
PITCH OF TEETH
KEYWAY
HOLE DIAMETER
SPIRAL OR HELIX ANGLE
FACE OF TOOTH
HEEL
CUTTING EDGE
END OR SIDE OF CUTTER
OUTSIDE DIAMETER
RA PD 256526

Figure 6. Milling cutter nomenclature.

(j) Spiral or helix angle. The spiral or helix angle, if present, refers to the spiral deflection of the teeth of the milling cutter.

(3) Types of teeth. The teeth of milling cutters are either right hand or left hand, viewed from the back of the machine. Right-hand milling cutters cut when rotated clockwise; left-hand milling cutters cut when rotated counterclockwise.

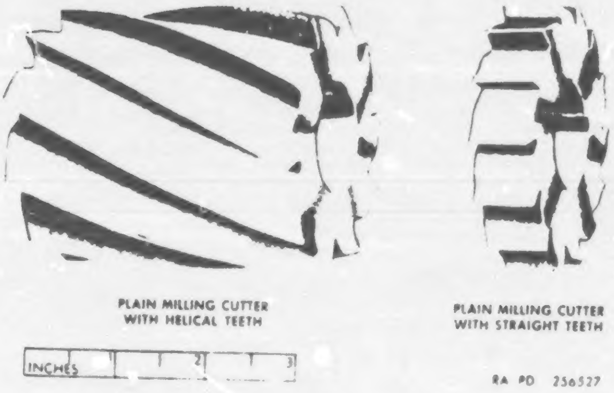
(a) Saw teeth. Saw teeth, similar to those shown in figure 6, are either straight or helical in the smaller sizes of plain milling cutters, metal slitting saw milling cutters, and end milling cutters. The cutting edge is usually given about 5° primary clearance. Sometimes the teeth are provided with offset nicks which break up the chips and make coarser feeds possible.

(b) Formed teeth. Formed teeth are usually specially made for machining irregular surfaces or profiles. The possible varieties of formed-tooth milling cutters are almost unlimited. The convex, concave, and corner-rounding milling cutters ((4) below) are of this type. Formed cutters are sharpened by grinding the faces of the teeth radially and repeated sharpenings are possible without changing the contour of the cutting edge.

(c) Inserted teeth. Inserted teeth are blades of high-speed steel inserted and rigidly held in a blank of machine steel or cast iron. Different manufacturers use different methods of holding the blades in place. Inserted teeth are especially economical and convenient for large-sized cutters because of their reasonable initial costs and because worn out or broken blades can be replaced easily.

(4) Kinds of milling cutters.

(a) Plain milling cutter (fig 7). The most common kind of milling cutter is known as a plain milling cutter. It is merely a cylinder having teeth cut on its periphery for producing a flat horizontal surface (or a flat vertical surface in the case of a vertical spindle machine). When the cutter is over 3/4 inch wide, the teeth are usually helical, which gives the tool a shearing action and requires less power, reduces chatter, and produces a smoother finish. Cutters with faces less than 3/4 inch wide are sometimes made with staggered or alternate right- and left-hand helical teeth. The shearing action, alternately right and left, eliminates side thrust on the cutter and arbor. When a plain milling cutter is considerably wider than the diameter, it is often called a slabbing cutter; slabbing cutters generally have nicked teeth. The nicked teeth prevent formation of overly large chips.


PLAIN MILLING CUTTER WITH HELICAL TEETH

PLAIN MILLING CUTTER WITH STRAIGHT TEETH

RA PD 256527

Figure 7. Plain milling cutters.

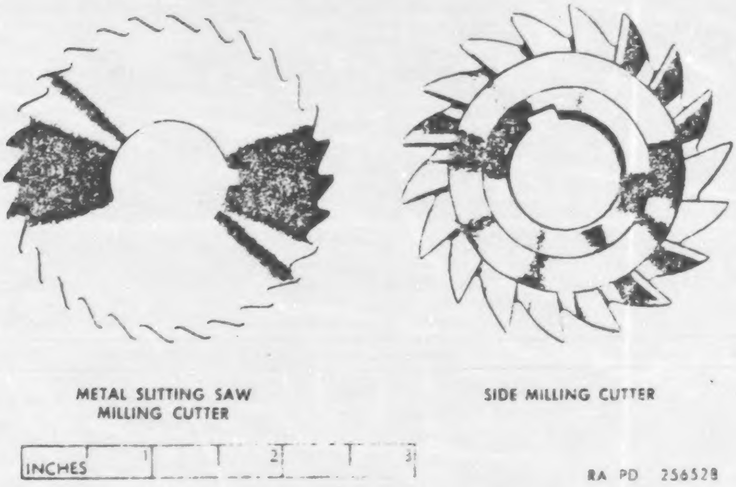
(b) Metal slitting saw milling cutter (fig 8). The metal slitting saw milling cutter is essentially a very thin plain milling cutter. It is ground slightly thinner toward the center to provide side clearance. It is used for metal sawing and for cutting narrow slots.

(c) Side milling cutters. Side milling cutters are essentially plain milling cutters with the addition of teeth on one or both sides.

1. A plain side milling cutter (fig 8) has teeth on both sides and on the periphery. When teeth are added to one side only, the cutter is called a half-side milling cutter and is

identified as being either a right-hand or left-hand cutter. Side milling cutters are generally used for slotting and straddle milling.

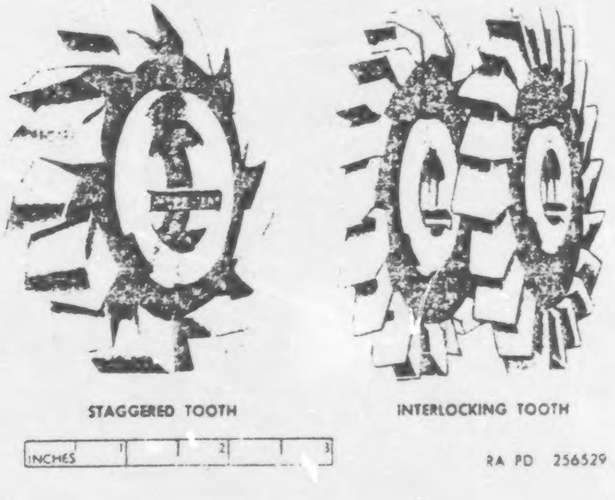
2. Interlocking tooth side milling cutters and staggered tooth side milling cutters (fig 9) are used for cutting relatively wide slots with accuracy. Interlocking tooth side milling cutters can be repeatedly sharpened without changing the width of the slot they will machine. After each sharpening, a washer is placed between the two cutters to compensate for the ground-off metal. The staggered tooth cutter is the most efficient type for milling slots where the depth exceeds the width.



METAL SLITTING SAW MILLING CUTTER

SIDE MILLING CUTTER

Figure 8. Side and metal slitting saw milling cutters.



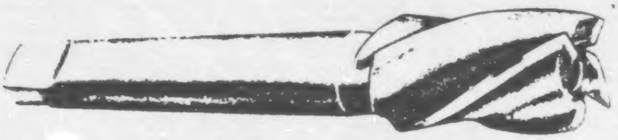
STAGGERED TOOTH

INTERLOCKING TOOTH

Figure 9. Staggered and interlocking tooth side milling cutters.

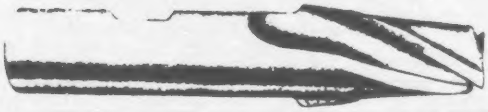
(d) End milling cutters.

1. End milling cutters, also called end mills, have teeth on the end as well as the periphery. The smaller end milling cutters have shanks (fig 10) for chuck mounting or direct spindle mounting. Larger end milling cutters (over 2 inches in diameter) are called shell end milling cutters and are mounted on arbors like plain milling cutters. End milling cutters are employed in the production of slots, keyways, recesses, and tangs. They are also used for milling the edges of workpieces.



LARGE TAPER SHANK SPIRAL FLUTE END MILLING CUTTER

SMALL TAPER SHANK SPIRAL FLUTE END MILLING CUTTER



STRAIGHT SHANK SINGLE-END SPIRAL FLUTE END MILLING CUTTER

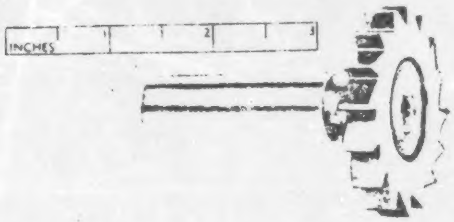
Figure 10. End milling cutters.

2. End milling cutters may have straight or spiral flutes. Spiral flute end milling cutters (fig 10) are classified as left-hand or right-hand cutters, depending on the direction of rotation of the flutes. If they are small cutters, they may have either a straight or tapered shank.

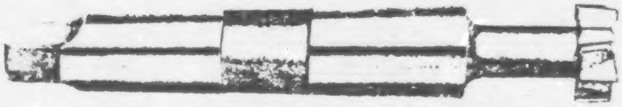
3. Several common types of end milling cutters are illustrated in figure 10. The most common end milling cutter is the spiral flute end milling cutter which contains four flutes. Single-end spiral flute end milling cutters are used for milling slots and keyways where no drilled hole is provided for starting the cut. These cutters drill their own starting holes. Straight flute end milling cutters are generally used for milling soft or tough materials while spiral flute cutters are used mostly for cutting steels.

(e) Face milling cutter. Face milling cutters are cutters of large diameter having no shanks. They are fastened directly to the milling machine spindle with adapters. Face milling cutters are generally made with inserted teeth of high-speed steel or tungsten carbide in a soft steel hub.

(f) T-slot milling cutter (fig 11). The T-slot milling cutter is used to machine T-slot grooves in worktables, fixtures, and other holding devices. The cutter has a plain or side milling cutter mounted to the end of a narrow shank. The throat of the T-slot is first milled with a side or end milling cutter and the headspace is then milled with the T-slot milling cutter.



WOODRUFF KEYSLOT MILLING CUTTER



T-SLOT MILLING CUTTER RA PD 256531

Figure 11. T-slot and woodruff keyslot milling cutters.

(g) Woodruff keyslot milling cutter (fig 11). The woodruff keyslot milling center is made in both shanked and arbor mounted types. The most common cutters of this type, those under 1-1/2 inches in diameter, are provided with a shank. They have teeth on the circumferential surface and slightly concave sides to provide clearance. These cutters are used for milling semicylindrical keyways in shafts.

(h) Angle milling cutters. An angle milling cutter is a cutter that has peripheral teeth which are neither parallel nor perpendicular to the cutter axis. Common operations performed with angle cutters are cutting teeth in ratchet wheels, milling dovetails, and cutting V-grooves. Angle cutters may be single-angle milling cutters (fig 12) or double-angle milling cutters. The single-angle cutter contains side cutting teeth on the flat side of the cutter. The angle of the cutter edge is usually 45°, 60°, or 80° for most operations. Double-angle cutters are used for helical milling and have one side at an angle of 12° to the axis and the other side at an included angle of 40°, 48°, or 50° to the first side.

(i) Concave and convex milling cutters (fig 13). Concave and convex milling cutters are formed tooth cutters shaped to produce concave and convex contours of one-half circle or less. The size of the cutter is specified by the diameter of the circular form the cutter produces.

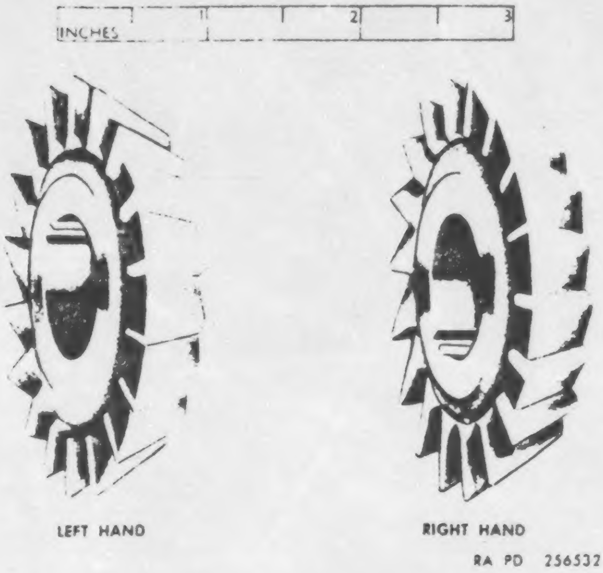

INCHES
1
2
3
LEFT HAND
RIGHT HAND
RA PD 256532

Figure 12. Single-angle milling cutters.

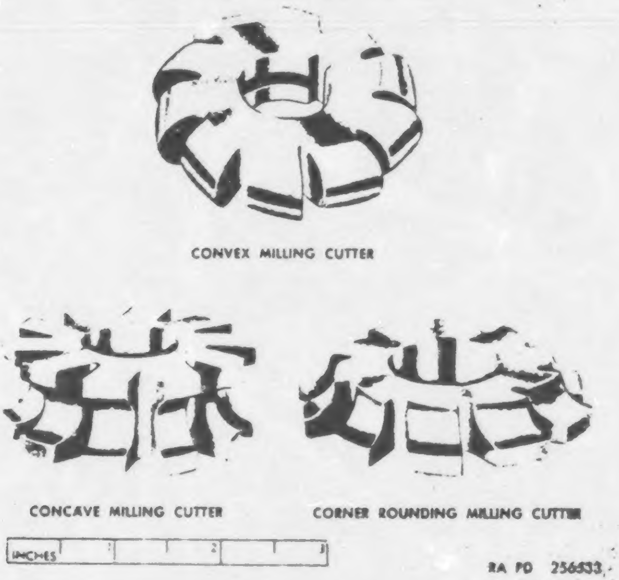

CONVEX MILLING CUTTER
CONCAVE MILLING CUTTER
CORNER ROUNDING MILLING CUTTER
INCHES
1
2
3
RA PD 256533

Figure 13. Concave, convex, and corner rounding milling cutters.

(j) Corner rounding milling cutter (fig 13). The corner rounding milling cutter is a formed tooth cutter used for milling rounded corners on workpieces up to and including one-quarter of a circle. The size of the cutter is specified by the diameter of the circular form as with concave and convex cutters.

(k) Gear hob. The gear hob is a formed-tooth milling cutter with helical teeth arranged like the thread on a screw. These teeth are fluted to produce the required cutting edges. Hobs are generally used for such work as finishing spur gears, spiral gears, and worm wheels. They may also be used for cutting ratchets and spline shafts.

(l) Special shape formed milling cutter. Formed milling cutters have the advantage of being adaptable to any specific shape for special operations. The cutter is made specially for each specific job. The cutter can be sharpened many times without destroying the shape of the cut.

b. Selection of milling cutters. The following factors should be considered in the choice of milling cutters.

(1) Type of machine to be used. High-speed steel, Stellite, and cemented carbide cutters have the distinct advantage of being capable of rapid production when used on a machine that can reach the proper speed.

(2) Method of holding the workpiece. For example, 45° angular cuts may either be made with a 45° single-angle milling cutter while the workpiece is held in a swivel vise, or with an end milling cutter while the workpiece is set at the required angle in a universal vise.

(3) Hardness of the material to be cut. The harder the material, the greater will be the heat that is generated in cutting. Cutters should be selected for their heat-resisting properties.

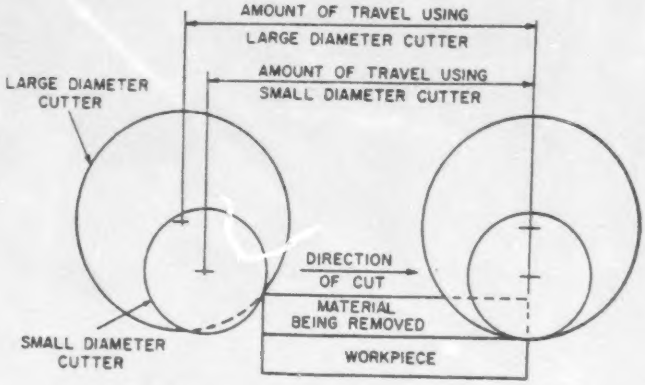
(4) Amount of material to be removed. A coarse-toothed milling cutter should be used for roughing cuts, whereas a fine toothed milling cutter may be used for light cuts and finishing operations.

(5) Number of pieces to be cut. For example, when milling stock to length, the choice of using a pair of side milling cutters to straddle the workpiece, a single-side milling cutter, or an end milling cutter will depend upon the number of pieces to be cut.

(6) Class of work being done. Some operations can be accomplished with more than one type of cutter such as in milling the square end on a shaft or reamer shank. In this case, one or two side milling cutters or an end milling cutter may be used. However, for the majority of operations, cutters are specially designed and named for the operation they are to accomplish.

(7) Rigidity and size of the workpiece. The milling cutter used should be small enough in diameter so that the pressure of the cut will not cause the workpiece to be sprung or displaced while being milled.

(8) Size of the milling cutter. In selecting a milling cutter for a particular job, it should be remembered that a small diameter cutter will pass over a surface in a shorter time than a large diameter cutter which is fed at the same speed. This fact is illustrated in figure 14.


AMOUNT OF TRAVEL USING
LARGE DIAMETER CUTTER
AMOUNT OF TRAVEL USING
SMALL DIAMETER CUTTER
LARGE DIAMETER CUTTER
DIRECTION OF CUT
MATERIAL BEING REMOVED
SMALL DIAMETER CUTTER
WORKPIECE

RA PD 256534

Figure 14. Effect of milling cutter diameter on workpiece travel.

c. Care and maintenance of milling cutters.. The life of a milling cutter can be greatly prolonged by intelligent use and proper storage. General rules for the care and maintenance of milling cutters are given below.

(1) New cutters received from stock are usually wrapped in oil-paper which should not be removed until the cutter is used.

(2) Care should be taken to operate the machine at the proper speed for the cutter being used, as excessive speed will cause the cutter to wear rapidly from overheating.

(3) Whenever practicable, the proper cutting oil should be used on the cutter and workpiece during operation, since lubrication helps prevent overheating and consequent cutter wear.

(4) Cutters should be kept sharp, because dull cutters require more power to drive and this power being transformed into heat softens the cutting edges. Dull cutters should be marked and set aside for grinding.

(5) A cutter should never be operated backward because, due to the clearance angle, the cutter will rub producing a great deal of frictional heat. Operating the cutter backward may result in cutter breakage.

(6) Care should be taken to prevent the cutter from striking the hard jaws of the vise, chuck, clamping bolts, or nuts.

(7) A milling cutter should be thoroughly cleaned and lightly coated with oil before storing.

(8) Cutters should be placed in drawers or bins in such a manner that their cutting edges will not strike each other. Small cutters that have a hole in the center should be hung on hooks or pegs, while large cutters should be set on end. Taper and straight shank cutters may be placed in separate drawers, bins, or racks provided with suitable sized holes to receive the shanks.

5. ARBORS.

a. Description.

(1) An arbor is a shaft or mandrel used to mount cutting tools for machining operations. Arbors are used in the milling machine spindle to secure and to drive milling cutters that cannot be mounted directly in the spindle.

(2) Arbors are supplied with one of three tapers to fit the milling machine spindle, the Milling Machines Standard taper, the Brown and Sharpe taper, and the Brown and Sharpe taper with tang (fig 15).

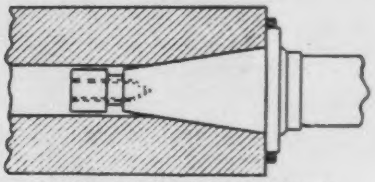
(3) The Milling Machine Standard taper (fig 15) is used on most machines of recent manufacture. It was originated by milling machine manufacturers to facilitate removal of the arbor from the spindle.

(4) The Brown and Sharpe taper (fig 15) is found mostly on older machines. Adapters or collets are used to adapt these tapers to fit machines whose spindles have Milling Machine Standard tapers.

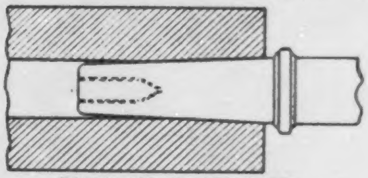
(5) The Brown and Sharpe taper with tang is used on some older machines. The tang engages a slot in the spindle to assist in driving the arbor.

b. Standard Milling Machine arbor (figs 16 and 17).

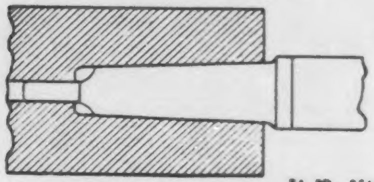
(1) The Standard Milling Machine arbor has a straight, cylindrical shape with a Standard Milling Machine taper on the driving end and a threaded portion on the opposite end to receive the arbor nut. One or more milling cutters may be placed on the straight cylindrical portion of the arbor and held in position by means of sleeves and the arbor nut. The Standard Milling Machine arbor is usually splined and keys are used to lock each cutter to the arbor shaft. These arbors are supplied in various lengths and standard diameters.



MILLING MACHINE STANDARD TAPER



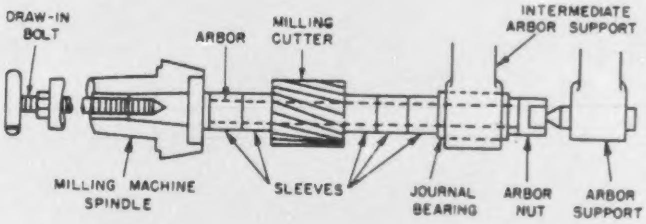
BROWN AND SHARPE TAPER



TAPER WITH TANG

RA PD 256539

Figure 15. Tapers used for milling machine arbors.


DRAW-IN BOLT
ARBOR
MILLING CUTTER
INTERMEDIATE ARBOR SUPPORT
MILLING MACHINE SPINDLE
SLEEVES
JOURNAL BEARING
ARBOR NUT
ARBOR SUPPORT

RA PD 256540

Figure 16. Standard milling machine arbor installed on the milling machine.

(2) The end of the arbor opposite the taper is supported by the arbor supports of the milling machine. One or more supports are used depending on the length of the arbor and the degree of rigidity required. The end may be supported by a lathe center bearing against the arbor nut (fig. 16) or by a bearing surface of the arbor fitting inside a bushing of the arbor support. Journal bearings are placed over the arbor in place of sleeves where an intermediate arbor support is positioned.

(3) The most common means of fastening the arbor in the milling machine spindle is by use of a draw-in bolt (fig. 16). The bolt threads into the taper shank of the arbor to draw the taper into the spindle and hold it in place. Arbors secured in this manner are removed by backing out the draw-in bolt and tapping the end of the bolt to loosen the taper.

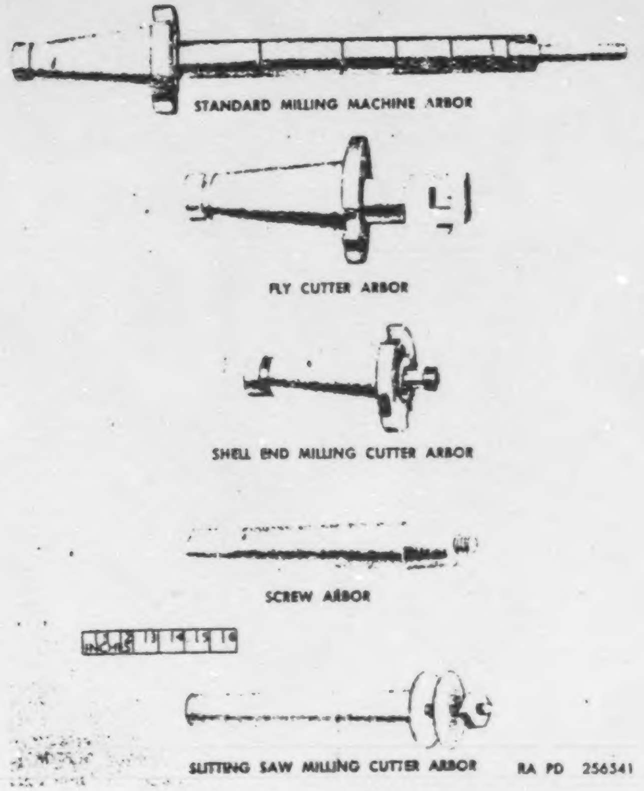

STANDARD MILLING MACHINE ARBOR
FLY CUTTER ARBOR
SHELL END MILLING CUTTER ARBOR
SCREW ARBOR
INCHES
SLITTING SAW MILLING CUTTER ARBOR
RA PD 256541

Figure 17. Types of milling machine arbors.

c. Screw arbor (fig 17). Screw arbors are used to hold small cutters that have threaded holes. These arbors have a taper next to the threaded portion to provide alinement and support for tools that require a nut to hold them against a taper surface. A right-hand threaded arbor must be used for right-hand cutters while a left-hand threaded arbor is used to mount left-hand cutters.

d. Slitting sawmilling cutter arbor (fig 17). The slitting sawmilling cutter arbor is a short arbor having two flanges between which the milling cutter is secured by tightening a clamping nut. This arbor is used to hold metal slitting sawmilling cutters used for slotting, slitting, and sawing operations.

e. End milling cutter arbor. The end milling cutter arbor has a bore in the end in which straight shank end milling cutters fit and are locked in place by means of a setscrew.

f. Shell end milling cutter arbor (fig 17). The shell end milling cutter arbor holds shell end milling cutters by means of a retaining screw in the end of the arbor. Two lugs on the arbor fit into the slots of the cutter to prevent the cutter from rotating on the arbor.

g. Fly cutter arbor (fig 17). The fly cutter arbor is used to support a single-edge lathe, shaper, or planer cutter bit for boring and gear cutting operations on the milling machine.

6. COLLETS AND SPINDLE ADAPTERS.

a. Description. Milling cutters that contain their own straight or tapered shanks are mounted to the milling machine spindle with collets or spindle adapters which adapt the cutter shank to the spindle.

b. Collets. Collets for milling machines serve to step up or increase taper sizes so that small shank tools can be fitted into large spindle recesses. They are similar to drilling machine sockets and sleeves except that their tapers are not alike.

c. Spindle adapters. Spindle adapters are used to adapt arbors and milling cutters to the standard tapers used for milling machine spindles. With the proper spindle adapters, any taper or straight shank cutter or arbor can be fitted to any milling machine if sizes and tapers are standard.

7. INDEXING FIXTURE.

a. Purpose. The indexing fixture (fig 18) is an indispensable accessory for the milling machine. Basically, it is a device for mounting workpieces and rotating them a specified amount about the workpiece axis, as from one tooth space to another on a gear or cutter.

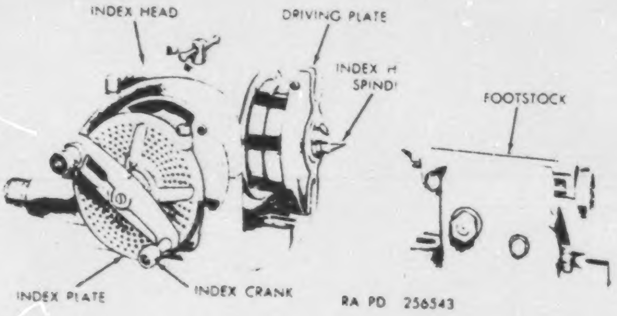


Figure 18. Indexing fixture.

b. Description. This index fixture consists of an index head, also called a dividing head, and a footstock, which is similar to the tailstock of a lathe. The index head and footstock attach to the worktable of the milling machine by T-slot bolts. An index plate containing graduations is used to control the rotation of the index head spindle. The plate is fixed to the index head, and an index crank, connected to the index head spindle by a worm gear and shaft, is moved about the index plate. Workpieces are held between centers by the index head spindle and footstock. Workpieces may also be held in a chuck, mounted to the index head spindle, or may be fitted directly into the taper spindle recess of some indexing fixtures.

c. Types. There are many variations of the indexing fixture. Universal index head is the name applied to an index head designed to permit power drive of the spindle so that helices may be cut on the milling machine. Gear cutting attachment is another name applied to an indexing fixture; in this case, one that is primarily intended for cutting gears on the milling machine.

8. HIGH-SPEED MILLING ATTACHMENT. The rate of spindle speed of the milling machine may be increased from 1-1/2 to 6 times by the use of the high-speed milling attachment. This attachment is essential when using cutters and twist drills which must be driven at a high rate of speed in order to obtain an efficient surface speed. The attachment is clamped to the column of the machine and is driven by a set of gears from the milling machine spindle.

9. VERTICAL SPINDLE ATTACHMENT. This attachment converts the horizontal spindle of a horizontal milling machine to a vertical spindle. It is clamped to the column and driven from the horizontal spindle. It incorporates provisions for setting the head at any angle, from the vertical to the horizontal, in a plane at right angles to the machine spindle. End milling and face milling operations are more easily accomplished with this attachment, due to the fact that the cutter and the surface being cut are in plain view.

10. UNIVERSAL MILLING ATTACHMENT. This device is similar to the vertical spindle attachment but it is more versatile. The cutter head can be swiveled to any angle in any plane, whereas the vertical spindle attachment only rotates in one plane from horizontal to vertical.

11. CIRCULAR MILLING ATTACHMENT. This attachment consists of a circular worktable containing T-slots for mounting of workpieces. The circular table revolves on a base which attaches to the milling machine worktable. The attachment can be either hand or power driven, being connected to the table drive shaft if power driven. It may be used for milling circles, arcs, segments, and circular slots, as well as for slotting internal and external gears. The table of the attachment is divided in degrees.

12. OFFSET BORING HEAD. The offset boring head is an attachment that fits to the milling machine spindle and permits a single-edge cutting tool, such as a lathe cutter bit, to be mounted off-center on the milling machine. Workpieces can be mounted in a vise attached to the worktable and can be bored with this attachment.

13. INDEXING WORKPIECES.

a. General. Indexing, as applied to machining practices, is the process of evenly dividing or spacing workpieces such as is required in the cutting of tooth spaces on gears, the milling of grooves in reamers and taps, and the forming of teeth on milling cutters. The index head of the indexing fixture is used for this purpose.

b. Index head. The index head of the indexing fixture (fig. 18) contains an indexing mechanism which is used to control the rotation of the index head spindle to space or divide a workpiece accurately. Figure 19 illustrates a simple indexing mechanism. It consists of a 40-tooth worm wheel fastened to the index head spindle, a single-cut worm, a crank for turning the worm shaft, and an index plate and sector. Since there are 40 teeth in the worm wheel, one turn of the index crank causes the worm wheel, and consequently the index head spindle, to make 1/40 of a turn; so 40 turns of the index crank revolve the spindle 1 full turn.

c. Plain indexing.

(1) General. The following principles apply to basic indexing of workpieces.

(a) Suppose it is desired to mill a spur gear with 8 equally spaced teeth. Since 40 turns of the index crank will turn the

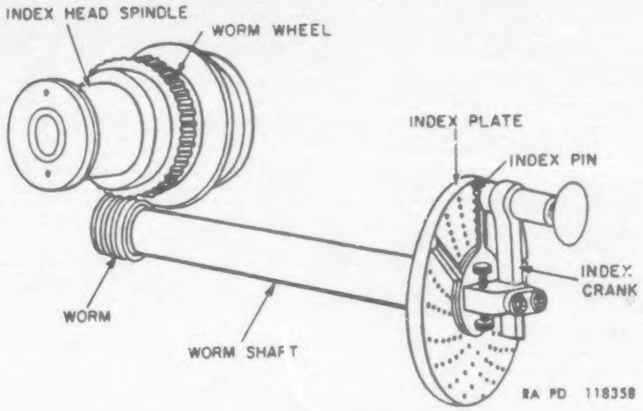


Figure 19. Simple indexing mechanism.

spindle 1 full turn, 1/8 of 40 or 5 turns of the crank after each cut will space the gear for 8 teeth. If it is desired to space equally for, say, 10 teeth, 1/10 of 40 or 4 turns would produce the correct spacing.

(b) The same principle applies whether or not the divisions required divide evenly into 40. For example, if it is desired to index for 6 divisions, 6 divided into 40 equals 6 and 2/3 turns; similarly, to index for, say, 14 spaces, 14 divided into 40 equals 2-6/7 turns. These examples may be multiplied indefinitely and from them the following rule is derived: To determine the number of turns of the index crank needed to obtain one division of any number of equal divisions on the workpiece, divide 40 by the number of equal divisions desired (provided the worm wheel has 40 teeth, which is standard practice).

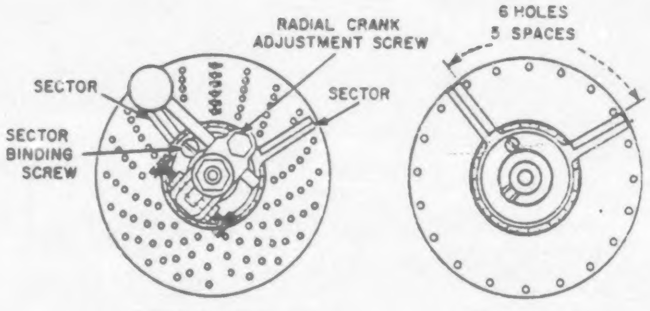
(2) Index plate. The index plate (fig. 20) is a round plate with a series of six or more circles of equally spaced holes; the index pin on the crank can be inserted in any hole in any circle. With the interchangeable plates regularly furnished with most index heads, the spacings necessary for most gears, bolt heads, milling cutters, splines, and so forth, can be obtained. The following sets of plates are standard equipment.

(a) Brown and Sharpe type, 3 plates of 6 circles each, drilled as follows:

Plate 1: 15, 16, 17, 18, 19, 20 holes.
Plate 2: 21, 23, 27, 29, 31, 33 holes.
Plate 3: 37, 39, 41, 43. 47, 49 holes.

(b) Cincinnati type, one plate drilled on both sides with circles divided as follows:

First side: 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43 holes.
Second side: 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66 holes.



INDEX PLATE WITH CRANK AND SECTOR

OPERATION OF SECTOR

RA PD 256625

Figure 20. Index plate and sector.

(3) Indexing operation. The two following examples show how the index plate is used to obtain any desired part of a whole spindle turn by plain indexing.

(a) To mill a hexagon. Using the rule previously given in (1)(b) above, divide 40 by 6, which equals 6-2/3 turns, or 6 full turns plus 2/3 of a turn on any circle whose number of holes is divisible by 3. Therefore, 6 full turns of the crank plus 12 spaces on an 18-hole circle, or 6 full turns plus 26 spaces on a 39-hole circle will produce the desired rotation of the workpiece.

(b) To cut a gear of 42 teeth. Using the rule again, divide 40 by 42 which equals 40/42 or 20/21 turns, or 40 spaces on a 42-hole circle, or 20 spaces on a 21-hole circle. To use the rule given, select a circle having a number of holes divisible by the denominator of the required fraction of a turn reduced to its lowest terms. The number of spaces between holes gives the desired fractional part of the whole circle. When counting holes, start with the first hole ahead of the index pin.

(4) Sector. The sector (fig. 20) indicates the next hole in which the pin is to be inserted and makes it unnecessary to count holes when moving the index crank after each cut. It consists of two radial, beveled arms which can be set at any angle to each other and then moved together around the center of the index plate. Suppose that, as shown in figure 21, it is desired to make a series of cuts, moving the index crank 1-1/4 turns after each cut. Since the circle illustrated has 20 holes, turn the crank 1 full turn, plus 5 spaces, after each cut. Set the sector arms to include the desired fractional part of a turn, or 5 spaces between the beveled edges of its arms, as shown. If the first cut is taken with the index pin against the left-hand arm, to take the next cut, move the pin once around the circle and into the hole against the right-hand arm of the sector. Before taking the second cut, move the arms so that the left-hand arm is again against the pin; this moves the right-hand arm another five spaces ahead of the pin. Then take the second cut; repeat the operation until all the cuts have been completed.

Note. —It is good practice always to index clockwise on the plate.

d. Indexing in degrees. Workpieces can be indexed in degrees as well as fractions of a turn with the usual index head. There are 360° in a complete circle and 1 turn of the index crank revolves the spindle 1/40 of a revolution or 9°. Therefore, 1/9 turn of the crank rotates the spindle 1°. Workpieces can therefore be indexed in degrees by using a circle of holes divisible by 9. For example, moving the crank 2 spaces on an 18-hole circle, 3 spaces on a 27-hole circle, or 4 spaces on a 36-hole circle will rotate the spindle 1°. Smaller crank movements further subdivide the circle: moving 1 space on an 18-hole circle turns the spindle 1/2° (30 min.); 1 space on a 27-hole circle turns the spindle 1/3° (20 min.); and so forth.

14. GENERAL MILLING OPERATIONS.

a. General. The success of any milling operation depends to a great extent upon the judgment in setting up the job, selecting the proper milling cutter, and holding the cutter by the best means under the circumstances. Some fundamental practices have been proved by experience to be necessary for good results on all jobs. Some of these practices are mentioned below.

(1) Before setting up a job, be sure that the workpiece, the table, the bore in the spindle, and the arbor or cutter shank are all clean and free from chips, nicks, or burs.

(2) Set up every job as close to the milling machine column as the circumstances permit.

(3) Do not select a milling cutter of larger diameter than is necessary.

(4) Keep milling cutters sharp at all times.

(5) Do not change feeds or speeds while the milling machine is in operation.

(6) Always lower the table before backing the workpiece under a revolving milling cutter.

(7) Feed the workpiece in a direction opposite to the rotation of the milling cutter, except when milling long or deep slots or when cutting off stock.

(8) Never run a milling cutter backward.

(9) When using clamps to secure workpieces, be sure that they are tight and that the piece is held so that it will not spring or vibrate under cut.

(10) Use a recommended cutting oil liberally.

(11) Keep chips away from the table and from around the workpiece; brush them out of the way by any convenient means, but do not do so by hand or with waste.

(12) Use good judgment and common sense in planning every job, and profit by previous mistakes.

b. Operations. Milling operations may be classified under four general headings as follows:

(1) Face milling - machining flat surfaces which are at right angles to the axis of the cutter.

(2) Plain or slab milling - machining flat surfaces which are parallel to the axis of the cutter.

(3) Angular milling - machining flat surfaces which are at an inclination to the axis of the cutter.

(4) Form milling - machining surfaces having an irregular outline.

15. SPEEDS FOR MILLING CUTTERS.

a. General. The speed of a milling cutter is the distance in feet per minute each tooth travels as it cuts its chip. The number of spindle revolutions per minute necessary to give a desired peripheral speed depends on the size of the milling cutter. The best speed is determined by the kind of material being cut and the material, size, and type of cutter used. The smoothness of finish desired and power available are other factors relating to cutter speed.

b. Selecting proper cutting speed.

(1) The approximate values given in table I may be used as a guide for selecting the proper cutting speed. If the operator finds that the machine, the milling cutter, or the workpiece cannot be handled suitably at these speeds, immediate readjustment should be made.

(2) Table I lists speeds for high-speed steel milling cutters. If carbon steel cutters are used, the speed should be about one-half the recommended speed in the table. If carbide-tipped cutters are used, the speed can be double.

(3) For roughing cuts, a moderate speed and coarse feed often give best results; for finishing cuts, the best practice is to reverse these conditions, using a higher speed and a lighter feed.

c. Speed computation.

(1) The formula for calculating spindle speed in revolutions per minute is as follows:

$$\text{r.p.m.} = \frac{12\ \text{f.p.m.}}{\pi D}$$

where, r.p.m. = spindle speed (in revolutions per minute);
f.p.m. = cutting speed of milling cutter (s.f.p.m. (surface ft. per min.));
π = 3.14
D = Diameter of milling cutter (in in.).

For example, the spindle speed for machining a piece of steel at a speed of 35 s.f.p.m. with a cutter 2 inches in diameter is calculated as follows:

$$\text{r.p.m.} = \frac{12 \text{ f.p.m.}}{\pi D} = \frac{12 \times 35}{3.14 \times 2} = 66.9 \text{ r.p.m.}$$

Therefore, the milling machine spindle would be set for approximately 67 r.p.m.

ABLE I. MILLING MACHINE CUTTING SPEEDS FOR HIGH-SPEED STEEL MILLINC CUTTERS.

Material	Cutting speed (sfpm)[1] [2]			
	Plain milling cutters		End milling cutters	
	Roughing	Finishing	Roughing	Finishing
Aluminum	400 to 1,000	400 to 1,000	400 to 1,000	400 to 1,000
Brass, composition	125 to 200	90 to 200	90 to 150	90 to 150
Brass, yellow	150 to 200	100 to 250	100 to 200	100 to 200
Bronze, phosphor and manganese.	30 to 80	25 to 100	30 to 80	30 to 80
Cast iron (hard)	25 to 40	10 to 30	25 to 40	20 to 45
Cast iron (soft and medium).	40 to 75	25 to 80	35 to 65	30 to 80
Monel metal	50 to 75	50 to 75	40 to 60	40 to 60
Steel, hard	25 to 50	25 to 70	25 to 50	25 to 70
Steel, soft	60 to 120	45 to 110	50 to 85	45 to 100

[1] For carbon steel cutters, decrease values by 50 percent.

[2] For carbide-tipped cutters, increase values by 100 percent.

(2) Table II is provided to facilitate spindle speed computations for standard cutting speeds and standard milling cutters.

16. FEEDS FOR MILLING.

a. General. The rate of feed, or the speed at which the workpiece passes the cutter, determines the time required for cutting a job.

b. Designation of feed. The feed of the milling machine may be designated either in "inches per minute" or "thousandths of an inch per revolution of the spindle."

(1) The inches per minute system is used in the newer machines, in which feed and spindle speed operate independently of each other.

(2) The thousandths of an inch per revolution of spindle system is used on the cone drive machines on which speed and feed are interdependent, and a change in speed causes a similar change in feed.

17. CUTTING OILS.

a. Purpose. The major advantage of a cutting oil is that it reduces frictional heat, thereby giving longer life to the cutting edges of the teeth. The oil also serves to lubricate the cutter face and to flush away the chips, consequently reducing the possibility of marring the finish.

TABLE II. MILLING CUTTER ROTATIONAL SPEEDS.

Diameter of cutter (in.)	Cutting speed (sfpm)													
	25	30	35	40	50	60	70	80	90	100	120	140	160	200
	Cutter revolutions per minute													
1/4	382	458	535	611	764	917	1, 070	1, 222	1, 376	1, 528	1, 834	2, 139	2, 445	3, 056
5/16	306	367	428	489	611	733	856	978	1, 100	1, 222	1, 436	1, 711	1, 955	2, 444
3/8	255	306	357	408	509	611	713	815	916	1, 018	1, 222	1, 425	1, 629	2, 036
7/16	218	262	306	349	437	524	611	699	786	874	1, 049	1, 224	1, 398	1, 748
1/2	191	229	268	306	382	459	535	611	688	764	917	1, 070	1, 222	1, 528
5/8	153	184	214	245	306	367	428	489	552	612	736	857	979	1, 224
3/4	127	153	178	203	254	306	357	408	458	508	610	711	813	1, 016
7/8	109	131	153	175	219	262	306	349	392	438	526	613	701	876
1	95. 5	115	134	153	191	229	267	306	344	382	458	535	611	764
1¼	76. 3	91. 8	107	123	153	183	214	245	274	306	367	428	490	612
1½	63. 7	76. 3	89. 2	102	127	153	178	204	230	254	305	356	406	508
1¾	54. 5	65. 5	76. 4	87. 3	109	131	153	175	196	218	262	305	349	438
2	47. 8	57. 3	66. 9	76. 4	95. 5	115	134	153	172	191	229	267	306	382
2½	38. 2	45. 8	53. 5	61. 2	76. 3	91. 7	107	122	138	153	184	213	245	306
3	31. 8	38. 2	44. 6	51	63. 7	76. 4	89. 1	102	114	127	152	178	203	254
3½	27. 3	32. 7	38. 2	43. 6	54. 5	65. 5	76. 4	87. 4	98. 1	109	131✓	153	174	218
4	23. 9	28. 7	33. 4	38. 2	47. 8	57. 3	66. 9	76. 4	86	95. 6	115	134	153	191
5	19. 1	22. 9	26. 7	30. 6	38. 2	45. 9	53. 5	61. 1	68. 8	76. 4	91. 7	107	122	153
6	15. 9	19. 1	22. 3	25. 5	31. 8	38. 2	44. 6	51. 0	57. 2	63. 6	76. 3	89	102	127
7	13. 6	16. 4	19. 1	21. 8	27. 3	32. 7	38. 2	43. 7	49. 1	54. 6	65. 5	76. 4	87. 4	109
8	11. 9	14. 3	16. 7	19. 1	23. 9	28. 7	33. 4	38. 2	43	47. 8	57. 4	66. 9	76. 5	95. 6

b. Types. Cutting oil compounds for various metals are given in table III. In general, a simple coolant is all that is required for roughing. Finishing requires a cutting oil with good lubricating properties to help produce a good finish on the workpiece. Aluminum and cast iron are almost always machined dry.

c. Application. The cutting oil or coolant should be directed by means of a coolant drip can or pump system to the point where the cutter contacts the workpiece. Regardless of method used, the cutting oil should be allowed to flow freely over the workpiece and cutter.

TABLE III. CUTTING OILS FOR MILLING OPERATIONS.

Material	Cutting fluid	
	Roughing	Finishing
Aluminum	Dry.	Dry.
Brass, composition	Dry; soda water mixture.	Dry; turpentine.
Brass, yellow	Dry; soda water mixture.	Dry.
Bronze, phosphor and manganese.	Soluble cutting oil	Sulfurized fatty mineral cutting oil; pure lard cutting oil.
Cast iron (hard)	Dry; soda water mixture.	Dry; turpentine.
Cast iron (soft and medium).	Dry.	Dry.
Monel metal	Dry; soluble cutting oil.	Mineral fatty blend cutting oil.
Steel, hard	Soluble cutting oil; mineral fatty blend cutting oil.	Sulfurized fatty mineral cutting oil; pure lard cutting oil
Steel, soft	Soluble cutting oil.	Mineral fatty blend cutting oil.

18. PLAIN MILLING.

a. General. Plain milling, also called surface milling and slab milling, is the milling of flat surfaces with the milling cutter axis parallel to the surface being milled. Generally, plain milling is accomplished with the workpiece surface mounted parallel to the surface of the milling machine table and the milling cutter mounted on a standard milling machine arbor. The arbor is well supported in a horizontal plane between the milling machine spindle and one or more arbor supports.

b. Operation. A typical setup for plain milling is illustrated in figure 21. Note that the milling cutter is positioned on the arbor with sleeves so that it is as close as practical to the milling machine spindle while maintaining sufficient clearance between the vise and the milling machine column. This practice reduces torque in the arbor and permits more rigid support for the cutter.

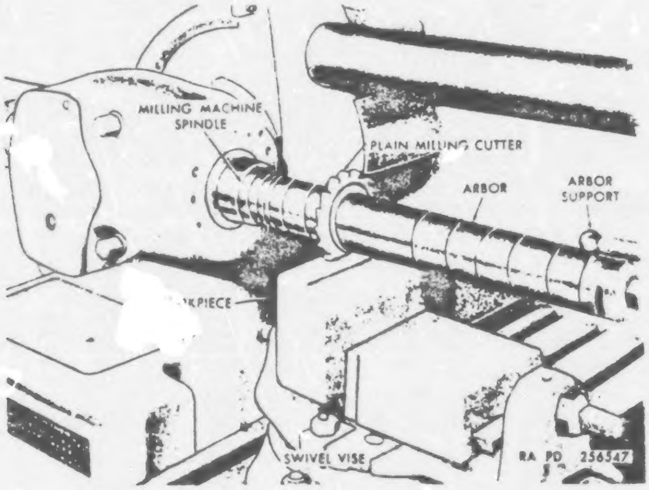


Figure 21. Plain milling operation.

19. ANGULAR MILLING.

a. General. Angular milling, or angle milling, is the milling of flat surfaces which are neither parallel nor perpendicular to the axis of the milling cutter. A single-angle milling cutter (fig 12) is used for this operation. The milling of dovetails is a typical example of angular milling.

b. Operation. When milling dovetails, the usual angle of the cutter is 45°, 50°, 55°, or 60° based on common dovetail designs. When cutting dovetails in the milling machine, the workpiece may be held in the vise, clamped to the table, or clamped to an angle plate. Figure 22 shows the workpiece mounted to a lathe face plate for angular milling with the milling and grinding lathe attachment. The tongue or groove is first roughed-out using a side milling cutter, after which the angular sides and base are finished with an angle milling cutter.

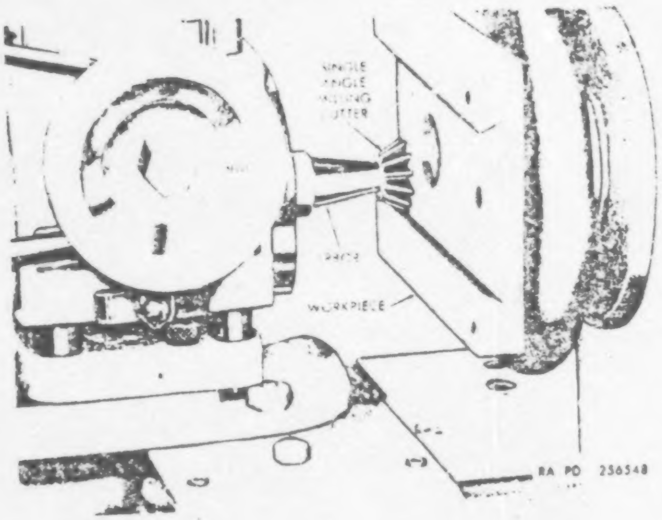


Figure 22. Angular milling of dovetail using the milling and grinding lathe attachment.

20. STRADDLE MILLING.

a. General. When two or more parallel vertical surfaces are machined at a single cut the operation is called straddle milling. Straddle milling is accomplished by mounting two side milling cutters on the same arbor, set apart so they straddle the workpiece.

b. Operation. Figure 23 illustrates a typical example of straddle milling. In this case, a spline is being cut but the same operation may be applied to the cutting of squares or hexagons on the end of a cylindrical workpiece. The workpiece is usually mounted between centers in the indexing fixture or mounted vertically in a swivel vise. The two side milling cutters are separated by spacers, washers, and shims so that the distance between the cutting teeth of each cutter is exactly equal to the width of the workpiece area required. When cutting a square by this method, two opposite sides of the square are cut, and then the spindle of the indexing fixture or the swivel vise is rotated 90°, and the other two sides of the workpiece are straddle milled.

21. FACE MILLING.

a. General. Face milling, also called end milling and side milling, is the machining of surfaces perpendicular to the axis of the milling cutter.

b. Purpose. Face milling cutters, end milling cutters (fig 24), and side milling cutters are used for face milling operations, the size and nature of the workpiece determining the type and size of cutter required.

c. Vertical operation. Figure 24 illustrates face milling performed with a swivel cutter head milling machine with its spindle in a vertical position. The workpiece is supported parallel to the table in a swivel vise.

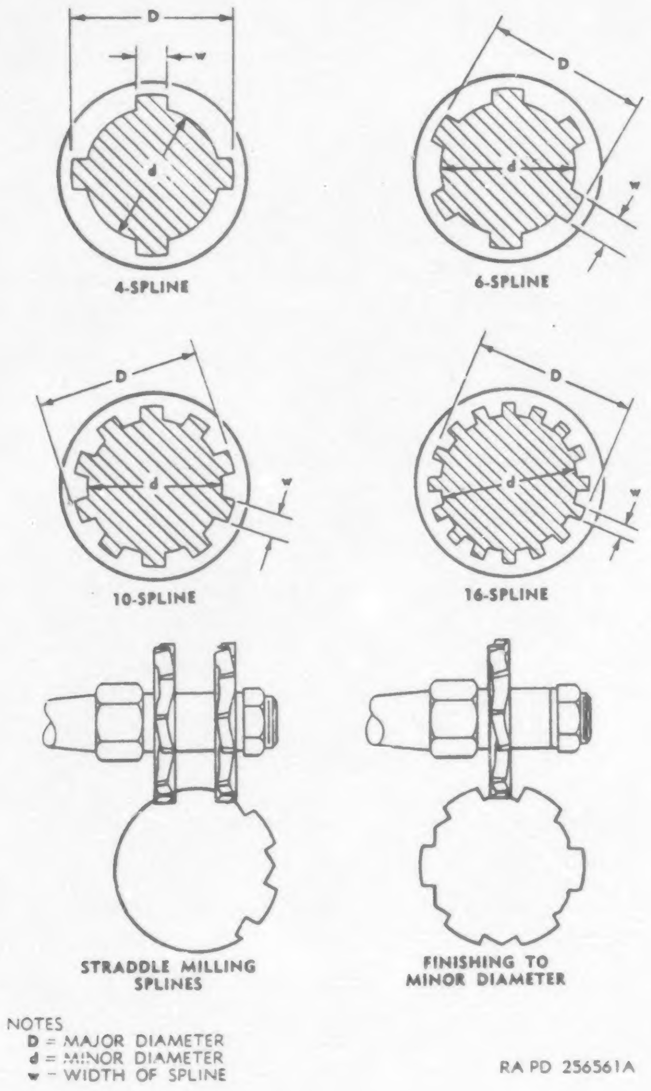

D
w
d
4-SPLINE
6-SPLINE
10-SPLINE
16-SPLINE
STRADDLE MILLING SPLINES
FINISHING TO MINOR DIAMETER
NOTES
D = MAJOR DIAMETER
d = MINOR DIAMETER
w - WIDTH OF SPLINE
RA PD 256561A

Figure 23. Milling spline shafts.

d. Horizontal operation. Angular surfaces can also be face milled on a swivel cutter head milling machine (fig 25). In this case, the workpiece is mounted parallel to the table and the cutter head is swiveled to bring the end milling cutter perpendicular to the surface to be produced.

22. GANG MILLING. When two or more parallel horizontal surfaces are milled at one cut, the operation is known as gang milling. The usual method is to mount two or more plain milling cutters of different diameters and widths on an arbor as shown in figure 26. The cutters so mounted are called a gang. The possible cutter combinations are unlimited and are determined in each case by the nature of the job.

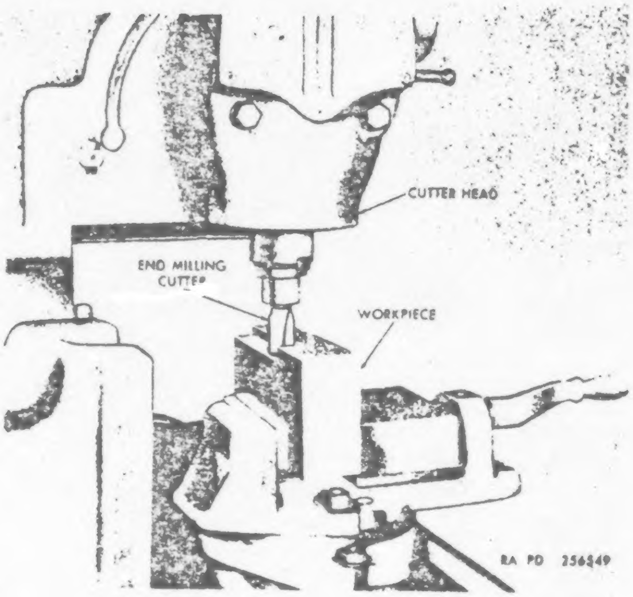

CUTTER HEAD
END MILLING CUTTER
WORKPIECE
RA PD 256549

Figure 24. Face milling with vertical milling machine spindle.

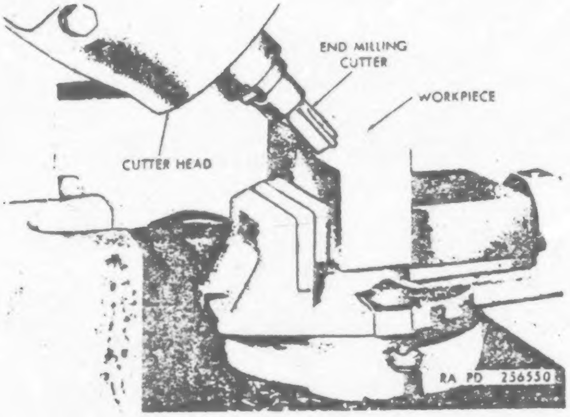

END MILLING CUTTER
WORKPIECE
CUTTER HEAD
RA PD 256550

Figure 25. Angular face milling.

23. FORM MILLING.

a. General. Form milling is the process of machining special contours composed of curves and straight lines, or entirely of curves, at a single cut. This is done with formed milling cutters, shaped to the contour to be cut.

b. Operation. The more common form milling operations involve the milling of half-round recesses and beads and quarter-round radii on workpieces (fig 27). This operation is accomplished by using convex, concave, and corner rounding milling cutters ground to the desired circle diameter.

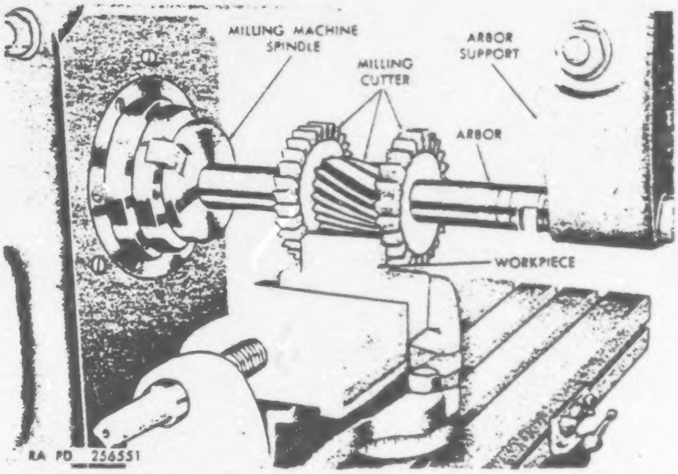

MILLING MACHINE SPINDLE
MILLING CUTTER
ARBOR SUPPORT
ARBOR
WORKPIECE
RA PD 256551

Figure 26. Gang milling operation.

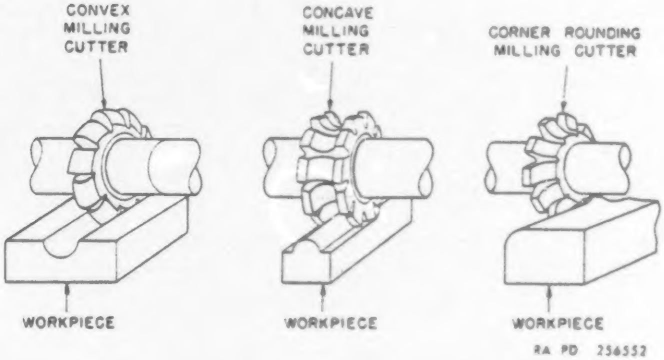

CONVEX MILLING CUTTER
CONCAVE MILLING CUTTER
CORNER ROUNDING MILLING CUTTER
WORKPIECE
WORKPIECE
WORKPIECE
RA PD 256552

Figure 27. Form milling operation.

c. Special uses. Other jobs for formed milling cutters include the milling of intricate patterns on workpieces and the milling of several complex surfaces in a single cut such as are produced by gang milling.

24. MILLING WOODRUFF KEYWAYS. The woodruff keyslot milling cutter (fig 28) is mounted in a spring collet or adapter which has been inserted in the spindle of the milling machine. With the milling cutter located over the position in which the keyway is to be cut, the workpiece should be raised or the cutter lowered until the cutter tears a piece of thin paper held between the peripheral teeth of the cutter and the workpiece. At this point the graduated dial on the vertical feed adjustment should be locked and the clamp on the table set. Using vertical feed, with the graduated dial as a guide, the workpiece is raised or the cutter lowered until the full depth of the keyslot is cut, completing the operation (fig 28).

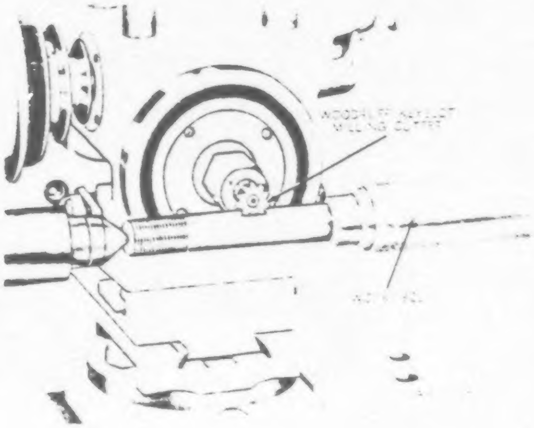


Figure 28. Woodruff keyway milling using the milling and grinding lathe attachment.

25. DRILLING.

a. General. The milling machine may be used effectively for drilling, since accurate location of the hole may be secured by means of the feed screw graduations. The spacing of holes in a circular path, such as the holes in an index plate, may be accomplished by indexing with the index head positioned vertically.

b. Operation. Twist drills may be supported in drill chucks fastened in the milling machine spindle or mounted directly in milling machine collets or adapters. The workpiece to be drilled is fastened to the milling machine table by means of clamps, vises, or angle plates.

26. BORING. Various types of boring toolholders may be used for boring on the milling machine, the boring tools being provided with either straight shanks to be held in chucks and holders, or taper shanks to fit collets and adapters. The two attachments most commonly used for boring are the fly cutter arbor and the offset boring head.

27. SUMMARY. The history, developments, and improvements of the milling machine were discussed in the above paragraphs. As you learned, the milling machine is very versatile. It can be used for many operations and has a wide variety of capabilities. The milling machine is excellent for forming flat surfaces, cutting dovetails and keyways, forming and fluting milling cutters and reamers, cutting gears, etc. Many special operations can be performed with the attachments available for milling machine use. You should be able to make more efficient use of this machine after having studied this lesson.

EXERCISE

101. What process is identical in method to milling?

    a. Straight arbor turning
    b. Circular sawing
    c. Surface grinding

102. What is the purpose of the ram on certain types of milling machines?

    a. Eliminates the dovetail between the knee and the table
    b. Provides additional rigidity to the column
    c. Provides a crossfeed for milling operations

103. The pitch of a milling cutter is determined by the

    a. types of teeth.
    b. number of teeth.
    c. primary clearance angle.

104. Which angle is necessary to prevent the teeth of the cutter from rubbing against the workpiece after it makes its cut?

    a. Spiral or helix deflection
    b. Secondary clearance
    c. Primary clearance

105. On a plain milling cutter, what is an advantage of helical teeth over straight teeth?

    a. Allows faster cutting action
    b. Produces a smoother cut
    c. Does not require large lands

106. Which type milling cutter is ground slightly thinner toward the center to allow for side clearance?

    a. Slitting
    b. Plain
    c. Straight

107. What is the MOST efficient milling cutter when the depth of the slot exceeds the width?

    a. Staggered tooth
    b. Concave
    c. Convex

108. Which action will eliminate side thrust on the arbor?

    a. Using a cutter with alternate helical teeth
    b. Installing a spring-loaded thrust washer
    c. Setting the ram in the correct position

109. What type arbor is used in a gear cutting operation on a milling machine?

    a. End
    b. Fly
    c. Slitting

110. What component would be used for MOST drilling operations and some cutting operations?

    a. High speed milling attachment
    b. Quick-change collet attachment
    c. Quick-change check

111. Which attachment or fixture can be swiveled to any angle or plane for milling operations?

    a. Universal milling
    b. Vertical spindle
    c. Offset boring head

112. How many turns of the indexing crank would be required to cut 12 equally spaced teeth in a gear?

    a. 6-1/3
    b. 6-1/4
    c. 3-1/3

113. How many degrees will the index head move in 10 complete turns of the index crank?

    a. 90
    b. 66
    c. 40

114. How many revolutions per minute must a 3-1/2-inch cutter turn if the cutting speed is 120 surface feet per minute?

    a. 91.7
    b. 115
    c. 131

115. What tool is BEST suited for boring?

    a. Fly cutter
    b. Special reamer
    c. End mill

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 424	Machine Shop Practice
Lesson 8.	Lathe
Credit Hours	Three
Lesson Objective	After studying this lesson you will be able to: 1. Discuss origin, history, purpose, types, use, nomenclature, and operation of the lathe. 2. Discuss as to types, use, mounting, and care of lathe accessory attachments to include cutting tools, cutting tool holders, chucks, faceplates, centers, dogs, mandrels, rests, toolpost grinding machine, and milling and grinding lathe attachments. 3. List, name, and explain the various functions (operations) that can be performed on the lathe.
Text	Attached Memorandum
Materials Required	None
Suggestions	If possible, visit a machine shop and observe the methods used in lathe operations.

STUDY GUIDE AND ATTACHED MEMORANDUM

1. INTRODUCTION.

a. Origin of the lathe. Perhaps the earliest of all machine tools, the lathe, was known to Leonardo da Vinci who drew several sketches of lathes in his notebook at the end of the 15th century. The earliest type of lathe, the bow lathe, was operated by a cord held taut by a piece of bowed wood and given a couple of turns around the workpiece. The operator rotated the workpiece by drawing the bow back and forth. The bow lathe evolved into the pole lathe in which the bow was replaced by a tree branch or wooden strip above the machine and a foot lever beneath the machine. With this arrangement, the operator treaded on the foot lever to pull the cord downward and rotate the workpiece. The tree branch or wooden strip would spring downward, being connected to the other end of the cord, and when the foot lever was released, the branch or strip would return the cord and foot lever to their original positions. The wooden strip or "lathe" used to spring the cord on these early pole lathes probably accounts for the name "lathe" being applied to the turning machine.

282

b. Besson's lathe. A screw cutting lathe was made by Jacques Besson before 1568 although it appears that this innovation exerted little influence on later lathe design. Besson's lathe (fig 1) was driven by a cord passing over a pulley above the machine which, in turn, drove two other pulleys on the same shaft which rotated the workpiece and a crude, wooden lead screw. The other end of the cord supported a weight which replaced the conventional spring return of the overhead tree branch or wood strip. A slide rest was incorporated on this machine, perhaps the earliest application of a slide rest.

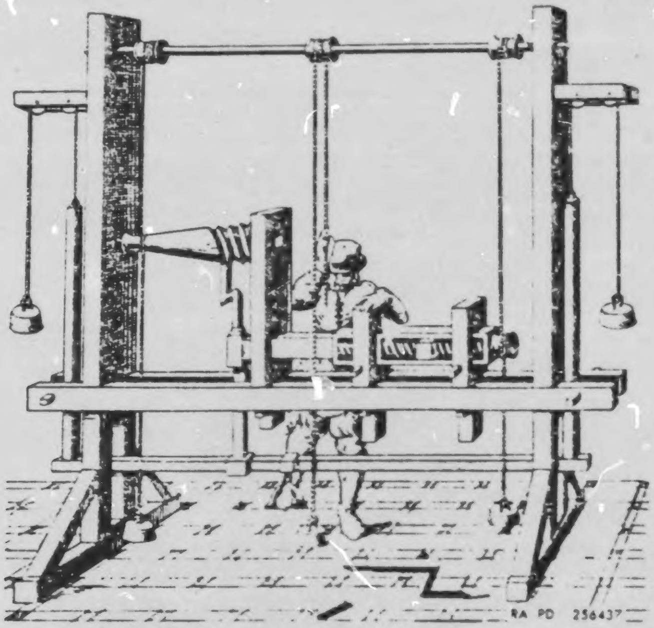


Figure 1. Besson's screw cutting lathe—1568.

c. Origin of screw cutting lathes. During the 17th and 18th centuries, lathes were used to advantage by clockmakers. The heavy-duty lathe was not yet practical and only light work could be performed. Screw cutting lathes fitted with slide rests for supporting tools were again developed in the first half of the 18th century, but these machines presented many difficulties in operation, and precision was unobtainable.

d. Development of screw cutting lathes. The first practical screw cutting lathe with a slide rest was developed by Henry Maudslay in England in 1797. This lathe incorporated a satisfactory lead screw which took Maudslay many years of experimentation to develop. The lathe was turned by a cord from a large wheel which was operated by a hand-crank. A later development of Maudslay's in 1800 introduced change gears whereby different pitches of screws could be cut from the same lead screw. Later Maudslay, while continuing his work on the screw, developed still better lead screws and placed metalworking on a solid foundation. In 1830, he built a giant lathe with a 9-foot faceplate capable of turning flywheels 20 feet in diameter and boring steam cylinders 10 feet in diameter for early steam engines.

e. Advancements. Lathe developments since the middle of the 19th century have not radically changed the Maudslay concept of the lathe. The major advances have been the improving of accuracy obtainable in workmanship, the designing of sturdier lathes, the increasing of the work speed, and the gradual conversion of manual operations to semiautomatic and automatic ones. The early cord drives were replaced by belt drives and eventually by electric motors. Lathes constructed before 1850 generally had wood beds upon which iron ways were mounted. The adaptation of the iron bed after 1850 made accurate turning of large workpieces practical. In 1853, an American named Freeland built a lathe having a back-geared head, a mechanism which with the lead screw, change gears, and slide rest constitutes the basic requirements of a modern engine lathe. The turret lathe was developed in America in 1890 and opened the way for the automatic lathes and automatic screw machines of today. The process was a gradual one, first making one motion and then another self-acting. The development of high-speed tool steel in 1898 and, later, carbide-tipped cutting tools in about 1925 permitted speed increases for the lathe and made semiautomatic and automatic lathes more desirable for production work.

2. PURPOSE. The lathe is a machine tool used principally for shaping articles of metal, wood, or other material by causing the workpiece to revolve while the cutter bit, held either by hand or by a mechanical holder, is applied to the workpiece. Principal capabilities of the lathe are the shaping of straight, tapered, or irregularly outlined cylinders, the facing or radial turning of cylindrical sections, the cutting of screw threads, and boring or enlarging internal diameters. The typical lathe provides a variety of rotating speeds and suitable manual and automatic controls for moving the cutting tool. In the hands of a competent operator, a lathe is the most versatile of all machine tools.

3. TYPES OF LATHES. Lathes can be conveniently classified as engine lathes, turret lathes, and special purpose lathes. All engine lathes have horizontal spindles and for that reason are sometimes referred to as horizontal lathes. The smaller lathes in all classes may be further classified as bench lathes or floor or pedestal lathes, the reference in this case being the means of support.

4. ENGINE LATHES.

a. General. The engine lathe is intended for general purpose lathe work and is the usual lathe found in the machine shop. The engine lathe may be bench type or floor mounted. The engine lathe consists mainly of a headstock, a tailstock, a carriage, and a bed upon which the tailstock and carriage move. Most engine lathes are back-geared to provide exceptionally slow spindle speeds and high torque which are required for the machining of large diameter workpieces and the taking of heavy cuts. The usual engine lathe has power longitudinal and crossfeeds for moving the carriage, and has a lead screw with gears to provide various controlled feeds for cutting threads. Lathes are made in various sizes, the size being determined by the diameter of the workpiece that can be swung in it and by the overall length of the bed. The swing is measured in inches and the bed is measured in feet. A third dimension is sometimes given: the distance between centers. This dimension, measured in inches, indicates the longest length of material that can be placed in the lathe.

b. Bench-type engine lathe (fig 2).

(1) The bench-type engine lathe is the most common general purpose screw cutting lathe in the small shop. It commonly has an 8- to 12-inch swing and a 3- to 5-foot bed length, the size being limited by the practicality of bench mounting. The bench upon which the lathe is mounted may be a standard wood-topped shop bench or a special metal lathe bench with drawers for storing the lathe accessories.

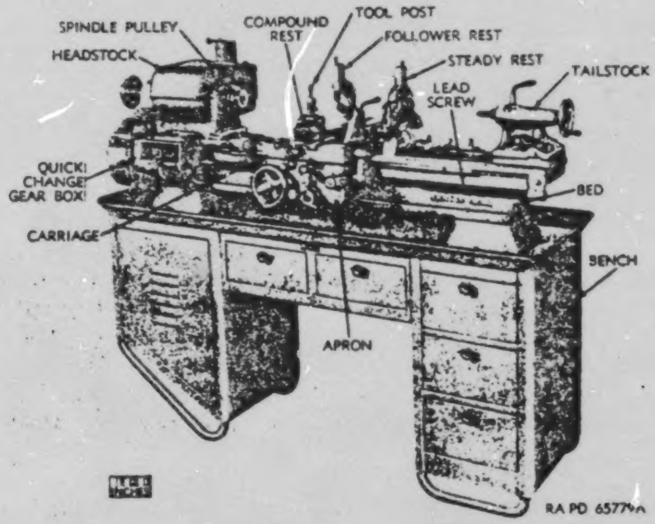


Figure 2. Bench-type engine lathe.

(2) The bench-type engine lathe is generally powered by an electric motor, mounted to the bench behind the lathe headstock, and driven by means of a flat leather belt. Some bench lathes use an underneath motor drive where the drive belt passes through a hole in the bench. This arrangement is convenient where space in the shop is limited. The bench-type engine lathe is generally equipped with the necessary tools, chucks, lathe dogs, and centers for normal operation. The lathe may have a quick-change gear box for rapid change of threading feeds, or may be supplied with loose gears which have to be installed singly or in combination to achieve the proper threading feeds. The bench lathe may or may not have a power-operated crossfeed drive.

(3) Lathe, Engine, Bench Mounted, solid Bed Type, 10 inch Swing, Series 2,000 Model 11 inch, Standard Modern Tool. This lathe (fig 3) is the newest type lathe added to the family of Army machinist tools. Figures 4 and 5 illustrate the various components of the lathe.

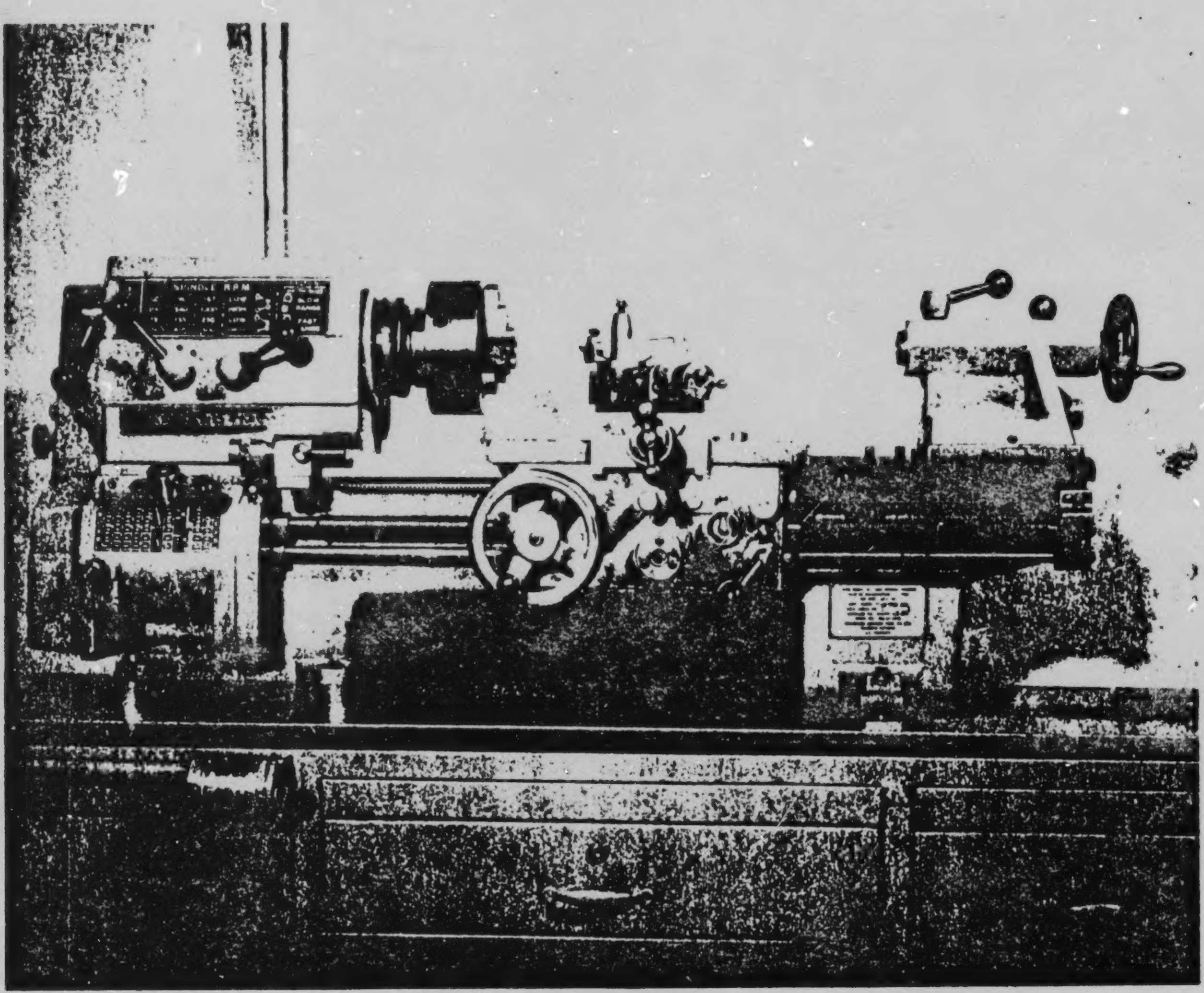


Figure 3. Bench-type engine lathe (standard modern tool, series 2,000 model 11 inch).

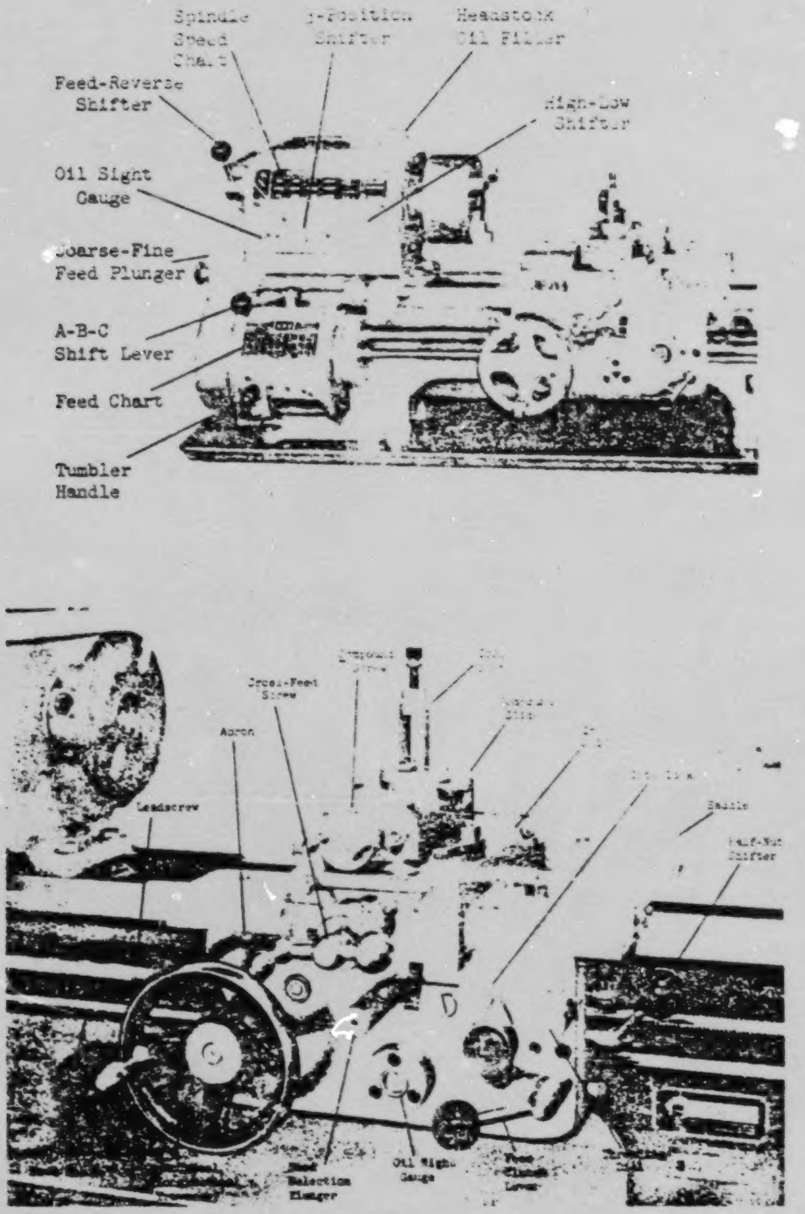

Spindle Speed Chart
3-Position Shifter
Headstock Oil Filler
Feed-Reverse Shifter
High-Low Shifter
Oil Sight Gauge
Coarse-Fine Feed Plunger
A-B-C Shift Lever
Feed Chart
Tumbler Handle
Cross-Feed Screw
Apron
Leadscrew
Saddle
Half-Nut Shifter
Feed Selection Plunger
Oil Sight Gauge
Feed Clutch Lever

Figure 5.

c. Floor-mounted engine lathe (fig 6). The floor-mounted engine lathe, or pedestal-type engine lathe, is inherently more rigid than the bench-type lathe and may have a swing as great as 16 or 20 inches and a bed length as great as 12 feet in length with 105 inches between centers. The drive motor is located in the pedestal beneath the lathe headstock. A tension release mechanism for loosening the drive belt is usually provided so that the drive belt may be quickly changed to different pulley combinations for speed changes. The headstock spindle is back-geared to provide slow spindle speeds, and a quick-change gear box for controlling the lead screw is present on all currently manufactured floor-mounted lathes. The floor-mounted engine lathe usually has a power-operated crossfeed mechanism.

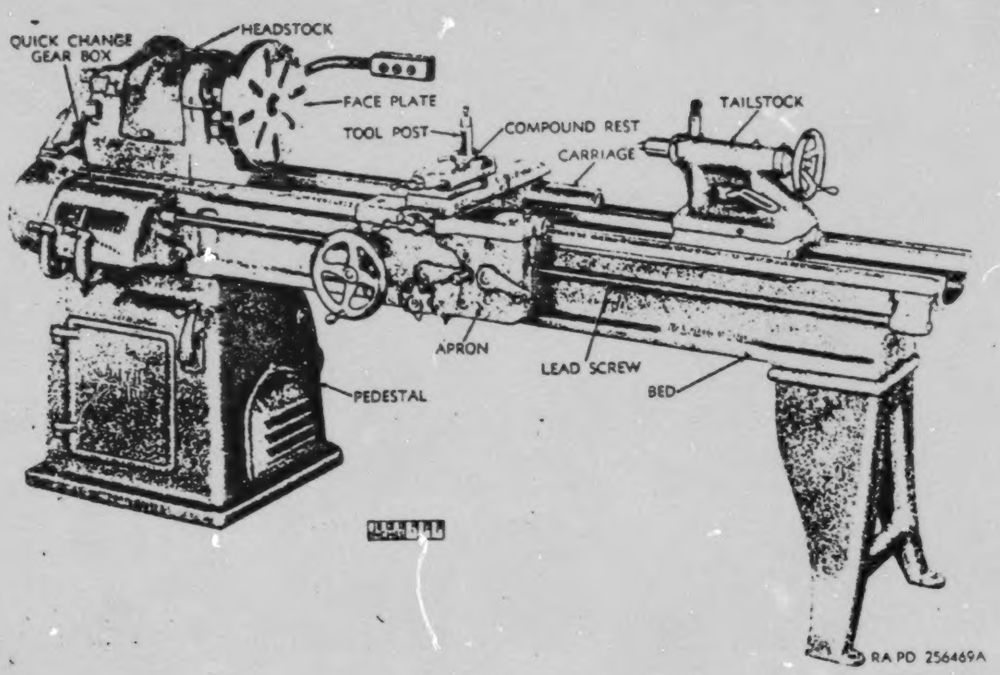


Figure 6. Floor-mounted engine lathe.

5. LATHE CUTTING TOOLS.

a. General. Lathe cutter bits may be considered as wedges which are forced into the material to cause compression with a resulting rupture or plastic flow of the material. This rupture or plastic flow is called cutting. To machine metal efficiently and accurately, it is necessary that the cutter bits have keen, well-supported cutting edges, and that they be ground for the particular metal being machined and the type of cut desired. Cutter bits are made from several types of steel, the most common of which are described in (1) through (5) below.

(1) Carbon steel. Carbon steel, or tool steel high in carbon content, hardens to a high degree when properly heated and quenched. The carbon-steel tool will give good results as long as constant care is taken to avoid overheating or "bluing," since the steel will lose its temper or hardness at a relatively low heat. For low-speed turning, carbon steel gives satisfactory results and is more economical than other materials.

(2) High-speed steel. High-speed steel is alloyed with tungsten and sometimes chromium, vanadium, or molybdenum. Although not as hard as properly tempered carbon steel, the majority of lathe cutting tools are made of high-speed steel because it retains its hardness at extremely high temperatures. Cutter bits made of this material can be used without damage at speeds and feeds which heat the cutting edges to a dull red.

(3) Stellite. Stellite, composed of chromium, and sometimes tungsten, must be cast into form and cannot be forged as can carbon and high-speed steels. Stellite cutter bits under favorable conditions will stand exceptionally fast speeds and heavy cuts.

(4) Tungsten carbide. Tungsten carbide is used to tip cutter bits when maximum speed and efficiency is required for materials which are difficult to machine. Although expensive, tungsten carbide tipped cutter bits are highly efficient for machining cast iron, alloyed cast iron, copper, brass, bronze, aluminum babbitt metal, and such abrasive nonmetallic materials as fiber, hard rubber, and bakelite. Cutter bits of this type require very rigid support and are usually held in openside toolposts. They require special grinding wheels for sharpening since tungsten carbide is too hard to be redressed on ordinary grinding abrasive wheels.

(5) Tantalum carbide and titanium carbide. Tantalum carbide and titanium carbide are also used to tip cutter bits (fig 9) for machining steel.

b. Terms and definitions applied to single-point cutter bits (fig 7). The terms and definitions described in (1) through (7) below are provided to orient the reader with respect to the basic areas and surfaces of the cutter bit.

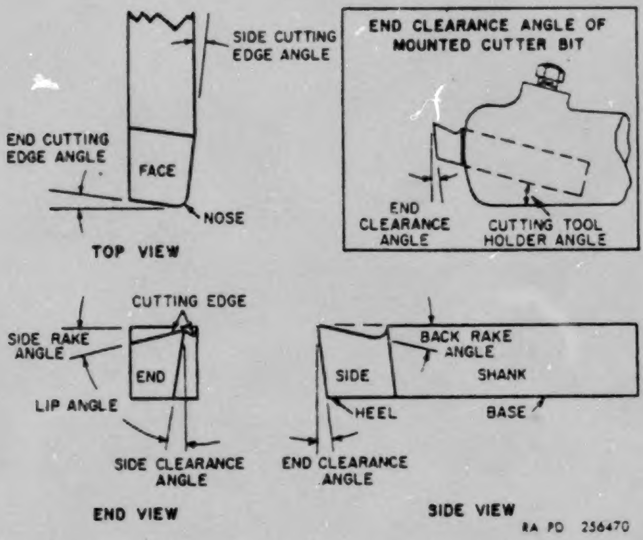

SIDE CUTTING EDGE ANGLE
END CUTTING EDGE ANGLE
FACE
NOSE
TOP VIEW
END CLEARANCE ANGLE OF MOUNTED CUTTER BIT
END CLEARANCE ANGLE
CUTTING TOOL HOLDER ANGLE
CUTTING EDGE
SIDE RAKE ANGLE
END
LIP ANGLE
SIDE CLEARANCE ANGLE
END VIEW
BACK RAKE ANGLE
SIDE
SHANK
HEEL
BASE
END CLEARANCE ANGLE
SIDE VIEW
RA PD 256470

Figure 7. Terms applied to single-point cutter bits.

(1) Shank. The shank is the body of the cutter bit on the end(s) of which the nose(s) is formed or the tip is mounted. On single-point cutter bits, the cutting edge is formed on one end of the shank.

(2) Nose. The nose is the part of the cutter bit which is shaped to produce the cutting edges.

(3) Face. The face of the cutter bit is the surface at the upper side of the cutting edge on which the chip strikes as it is separated from the workpiece.

(4) Side. The side of the cutter bit is the near-vertical surface which, with the end of the bit, forms the profile of the bit. The side is the leading surface of the cutter bit when cutting.

(5) Base. The base is the bottom surface of the shank of the cutter bit.

(6) End. The end of the cutter bit is the near-vertical surface which, with the side of the bit, forms the profile of the bit. The end is the trailing surface of the cutter bit when cutting.

(7) Heel. The heel is the portion of the cutter bit base immediately below and supporting the face.

c. Angles of cutter bits (fig 7). The successful operation of the lathe and the quality of work that may be achieved depend largely on the angles that form the cutting edge of the cutter bit. The profiles of the bit (e below) may be of any shape so long as the cutting edge is properly shaped. The five angles defined below are used to define the cutting edge, to prevent supporting surfaces of the bit from rubbing against the workpiece, and to establish a path for the chips being removed. Improperly ground angles will result in weakening and breaking of the cutting edge and overheating of the bit. Refer to d below for recommended angles for machining specific materials.

(1) Lip angle. The lip angle is the angle of keenness of the cutting edge. It is the angle included by the side and face of the cutter bit, measured at the cutting edge. The angle may be more acute for cutting soft, easily machined materials than for hard or tough materials since hard materials require more support for the cutting edge than do soft materials. If the lip angle is too acute to provide proper support for the cutting edge, the edge will break. If the lip angle is less acute or greater than required for support, the bit will cut unnecessarily slow. It has been found that a lip angle of 61° is most efficient for the machining of soft steel. Common cast iron requires a lip angle of 71° while very hard grades of cast iron, chilled iron, hard steel, bronze, etc., may require lip angles as great as 85°. If free cutting Bessemer screw stock is to be machined, the angle may be slightly less than 61°.

(2) Clearance (relief) angles. Only the cutting edge of the cutter bit must touch the workpiece, and therefore the end and side surfaces of the bit which form the profile of the cutting edge must be cut back or relieved on the underside to prevent their rubbing against the workpiece.

(a) End clearance (relief) angle. The end clearance angle is the angle formed by the end of the cutter bit and a line perpendicular to the diameter of the workpiece at the point of tool contact. If the bit is centered on the workpiece, the angle may be measured from the vertical.

(b) Side clearance (relief) angle. The side clearance angle is the angle measured between the side of the cutter bit at the cutting edge and the vertical.

(3) Rake angles. The angle which the face of the cutter bit makes with the horizontal is called the rake angle. Rake adds to the keenness of the tool and facilitates the removal of chips. If the slant of the rake is away from the workpiece, it is known as a back rake angle (fig 7); if the slant is in the direction of the workpiece axis, it is known as a side rake angle (fig 7). When a back rake angle slopes toward the shank of the bit, the bit is said to have a positive rake, and conversely, when the back rake angle slopes away from the shank, it is said to have a negative rake. Cutter bits may be ground with either a back rake or a side rake or a combination of both.

(4) Cutting toolholder angle. When determining the end clearance angle ((2)(a) above) and the back rake angle ((3) above), the cutting toolholder angle (fig 7) must be taken into consideration because any slant of the cutter bit shank will change these angles. When checking angles of the unmounted cutter bit, add the cutting toolholder angle to the end clearance angle and subtract the cutting toolholder angle from the back rake angle.

d. Recommended clearance and rake angles. Table I lists clearance angles and rake angles for various materials to be machined. When grinding cutter bits, the lip angle (c(1) above) should also be considered in selecting the proper angles from the table.

TABLE I. CLEARANCE AND RAKE ANGLES FOR LATHE CUTTER BITS

Material	Side clearance angle (deg.)	End clearance angle (deg.)	Back rake angle (deg.)	Side rake angle (deg.)
Aluminum	5-10	5-9	10-30	16-20
Brass	5-10	5-8	0-8	0-8
Bronze, free cutting	5-10	5-9	0-8	2-8
Bronze, tough	10-15	8-12	6-15	7-25
Cast iron	5-10	5-9	5-8	12-14
Copper	7-14	7-12	8-16	16-25
Magnesium alloy	6-10	6-10	5-9	3-5
Monel	6-15	6-13	4-10	10-14
Plastic, cast	12	10	30	25
Plastic, cold molded	10	10	0	0
Plastic, hot molded	6	6	10	20
Plastic, laminated	8	8	30	30
Steel, hard	5-10	5-9	6-14	10-14
Steel, soft	5-12	5-9	8-17	14-20
Steel, stainless	5-12	5-10	8-17	0-10
Steel, very hard	5-10	5-9	4-10	6-12
Wood	20	20	30	30

e. Common types of cutter bits (fig 8). Cutter bits are made from standard sizes of bar stock to fit into cutting toolholders which, in turn, are fastened to the toolpost of the lathe. The following cutter bits are identified by their function. If the cutter bit is to be used for heavy roughing where a finished surface is not expected, the nose should be ground with a very small radius (aprx. 1/64 in.). If the cutter bit is to be used for general shaping and finishing, the nose should be more rounded (aprx. 1/32- to 1/16-in. radius).

(1) Right-hand turning cutter bit. The right-hand turning cutter bit is shaped to be fed from right to left. The cutting edge is on the left side of the bit and the face slopes down away from the cutting edge, the left side and end of the tool are ground with sufficient clearance to permit the cutting edge to bear upon the workpiece without the heel of the bit rubbing against the workpiece. The right-hand turning cutter bit is ideal for taking light roughing cuts as well as general all-round machine work.

(2) Left-hand turning cutter bit. The left-hand cutter bit is just the opposite of the right-hand turning cutter bit, being designed to cut when fed from left to right. It is used for all-round machine work when right-to-left turning is impractical.

(3) Roundnose turning cutter bit (fig 8). The roundnose turning cutter bit is used for all-round machine work and may be used for taking light roughing or finishing cuts. Usually the face is ground with a right sloping side rake so that the bit may be fed from right to left, although it is often ground without any side rake so that the feed may be in either direction.

(4) Right-hand facing cutter bit. The right-hand facing cutter bit is intended for facing on right-hand side shoulders and the right end of the workpiece. The cutting edge is on the left-hand side of the bit, and the nose is sharp to permit machining a square corner. The direction of feed for the facing bit should be away from the axis of the workpiece.

(5) Left-hand facing cutter bit. The left-hand facing cutter bit is just the opposite of the right-hand facing cutter bit; it is intended for facing the left sides of shoulders.

(6) Parting cutter bit. The parting cutter bit has its principal cutting edge at the end. Both sides must have sufficient clearance to prevent binding and should be ground slightly narrower at the back than at the cutting edge. The bit is convenient for machining necks and grooves, square corners, etc., as well as for cutting off operations.

(7) Thread cutter bit. The thread cutter bit has its cutting edge ground to a symmetrical 60° angle and in this form will cut sharp V-threads. Usually the face of this bit is ground flat and has clearances ground on both sides so that it will cut on both sides. For American (National) Standard screw threads, the bit is further ground with a flat at the nose to cut the flat root of the thread. The width of the flat at the nose is determined by the pitch of the screw to be cut.

OS 424, 8-P11

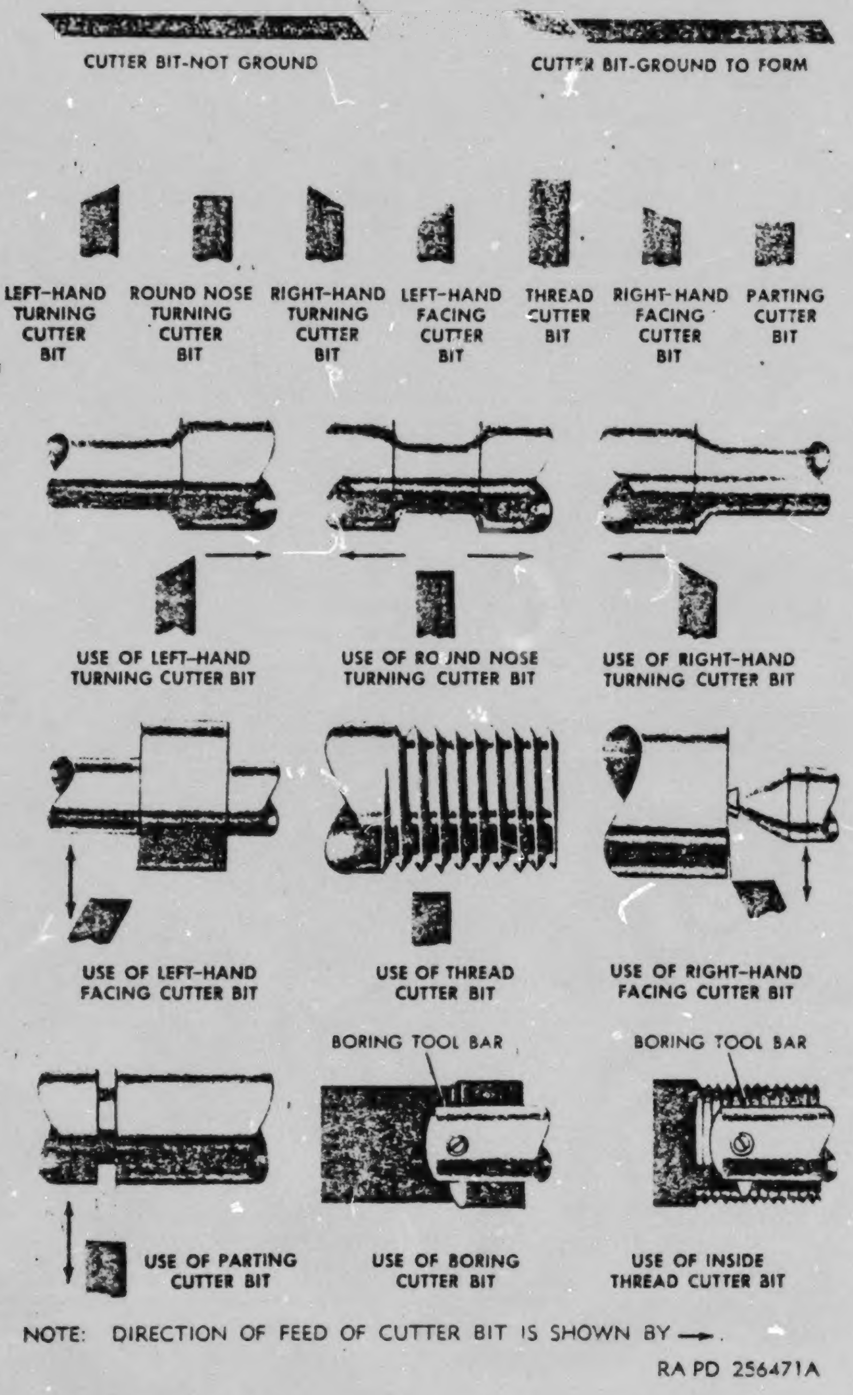
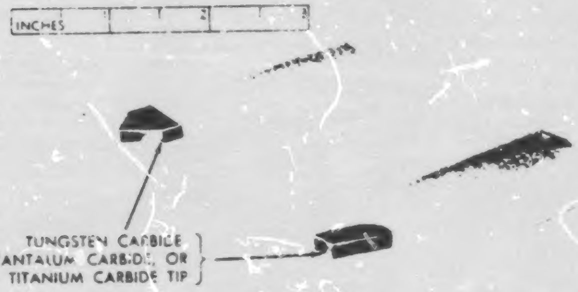

CUTTER BIT-NOT GROUND
CUTTER BIT-GROUND TO FORM
LEFT-HAND TURNING CUTTER BIT
ROUND NOSE TURNING CUTTER BIT
RIGHT-HAND TURNING CUTTER BIT
LEFT-HAND FACING CUTTER BIT
THREAD CUTTER BIT
RIGHT-HAND FACING CUTTER BIT
PARTING CUTTER BIT
USE OF LEFT-HAND TURNING CUTTER BIT
USE OF ROUND NOSE TURNING CUTTER BIT
USE OF RIGHT-HAND TURNING CUTTER BIT
USE OF LEFT-HAND FACING CUTTER BIT
USE OF THREAD CUTTER BIT
USE OF RIGHT-HAND FACING CUTTER BIT
BORING TOOL BAR
BORING TOOL BAR
USE OF PARTING CUTTER BIT
USE OF BORING CUTTER BIT
USE OF INSIDE THREAD CUTTER BIT
NOTE: DIRECTION OF FEED OF CUTTER BIT IS SHOWN BY →.
RA PD 256471A

Figure 8. Common types of cutter bits and their application.

f. Special types of lathe cutting tools. Besides the common cutter bits (e above), special lathe operations and heavy production work require special types of cutting tools. Some of the more common of these tools are described in (1) through (5) below.

(1) Tipped cutter bits (fig 9). Tungsten carbide, tantalum carbide, or titanium carbide-tipped cutter bits are commonly used in production work where high speeds and heavy cuts are necessary, and where exceptionally hard and tough materials are encountered. The tipped cutter bit generally has a shank size larger than the common cutter bit and is mounted in an open side cutting toolholder, a turret tool block, or directly in the toolpost of the lathe. Tipped cutter bits come in shapes for use in left-hand and right-hand turning, general purpose work, and cutting threads.



RA PD 256472

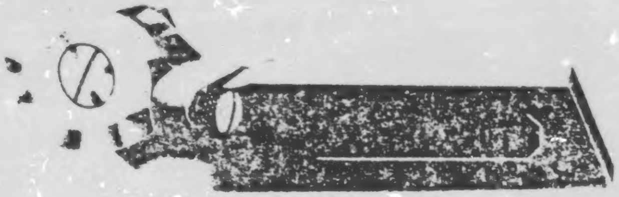
Figure 9. Tipped cutter bits.

(2) Thread cutting toolholder with cutter (fig 10). The thread cutting toolholder with cutter is used where considerable thread cutting is to be done. The cutter is formed with the correct thread contour and needs only grinding on the face to sharpen. The cutter is used in a specially designed toolholder which in turn mounts to the lathe toolpost.

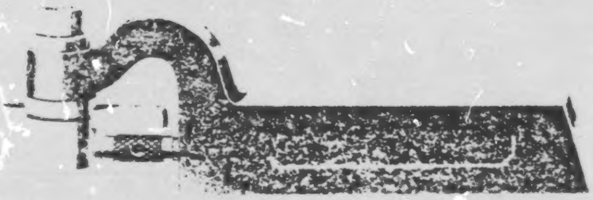
(3) Spring thread cutting toolholder with cutter bit (fig 10). The spring thread cutting toolholder with cutter bit consists of a specially designed cutting toolholder that mounts a thread cutter bit (e(7) above). The mounted cutter bit can be rotated to positions 30° either side of center to provide clearance for the holder when cutting threads close to either end of the workpiece. A spring device in the holder permits the cutter bit to spring downward under excess pressure, thereby preventing breakage of the cutter bit.

(4) Knurling tool (fig 10). The knurling tool consists of two cylindrical cutters called knurls which rotate in a specially designed toolholder. The knurls contain teeth which are rolled against the surface of the workpiece to form depressed patterns on the workpiece. The knurling tool accepts different pairs of knurls, each pair having a

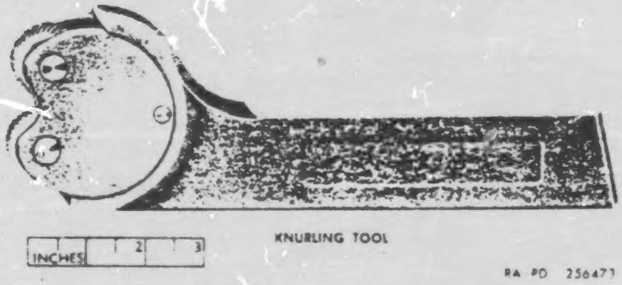
different pattern or a different pitch. The diamond pattern is most widely used, and is generally supplied in three pitches: 14-pitch, 21-pitch, and 33-pitch to produce coarse, medium, and fine diamond patterns (fig 11).



THREAD CUTTING TOOL HOLDER WITH CUTTER



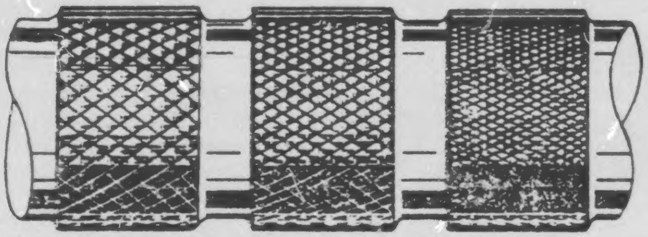
SPRING THREAD CUTTING TOOL HOLDER WITH CUTTER BIT



KNURLING TOOL

RA PD 256473

Figure 10. Special types of lathe cutting tools.


COARSE
14-PITCH
MEDIUM
21-PITCH
FINE
33-PITCH

RA PD 256474

Figure 11. Diamond knurling tool patterns.

(5) Boring tools. Boring tools are ground similar to left-hand turning cutter bits (e(2) above) and thread cutter bits (e(7) above) but with more attention given to the end clearance angle to prevent the heel of the bit from rubbing against the surface of the bore. The boring cutter bit (fig 8) is clamped to a boring tool bar which, in turn, is supported in a boring toolholder which mounts to the lathe toolpost.

g. Grinding of lathe cutter bits.

(1) General. The most satisfactory equipment for grinding cutter bits is the utility grinding machine with two 7-inch vitrified grinding abrasive wheels, 36 grain for rough grinding and 60 grain for fine grinding. The wheel should be run at a surface speed of about 5,000 feet per minute and should have close fitting guards and tool rests.

(2) Carbon-steel cutter bits. Carbon-steel cutter bits can be distinguished from high-speed steel cutter bits by taking a trial cut on the grinding abrasive wheel. If the bit is made of carbon steel, the sparks produced will be light orange colored; if the bit is made of high-speed steel, the sparks produced will be dark red. When grinding carbon-steel bits, a small container of water should be available for quenching the bit. A wet wheel or a water-drip grindstone may also be used for grinding bits made of carbon steel. In either case, water cooling is necessary to prevent the bit from losing its hardness by overheating.

(3) High-speed steel cutter bits. The high-speed steel cutter bit is identified by the red sparks given off when placed against the grinding abrasive wheel. High-speed steel cutter bits must be ground on a dry wheel; when hot they must never be dipped into water or the bit will crack and the cutting edge crumble.

(4) Carbide-tipped cutter bits. Cutter bits tipped with tungsten carbide, tantalum carbide, and titanium carbide cannot be ground with standard grinding abrasive wheels but must be ground using a special grinding wheel such as one that is diamond impregnated. Because the carbide is extremely brittle, it must be handled with extreme care. The cutting edge must always be well supported and the amount of grinding should be restricted to minor redressing of the cutting edge.

(5) Procedure. Figure 12 shows the steps involved in grinding a round-nose turning cutter bit to be fed from right to left for general turning operations. Other bits are ground in a similar manner. Remove the bit from the cutting toolholder before grinding to prevent damaging the cutting toolholder.

(a) Grind the left side of the bit, holding it against the grinding abrasive wheel at the correct angle to form the side clearance (step 1, fig 12). Use the coarse wheel to remove most of the metal and finish on the fine wheel.

(b) Grind the right side of the bit (step 2, fig 12). Do not remove any more metal than is necessary from this side as it requires no clearance and the more metal left on the bit the better the heat-dissipation qualities of the bit.

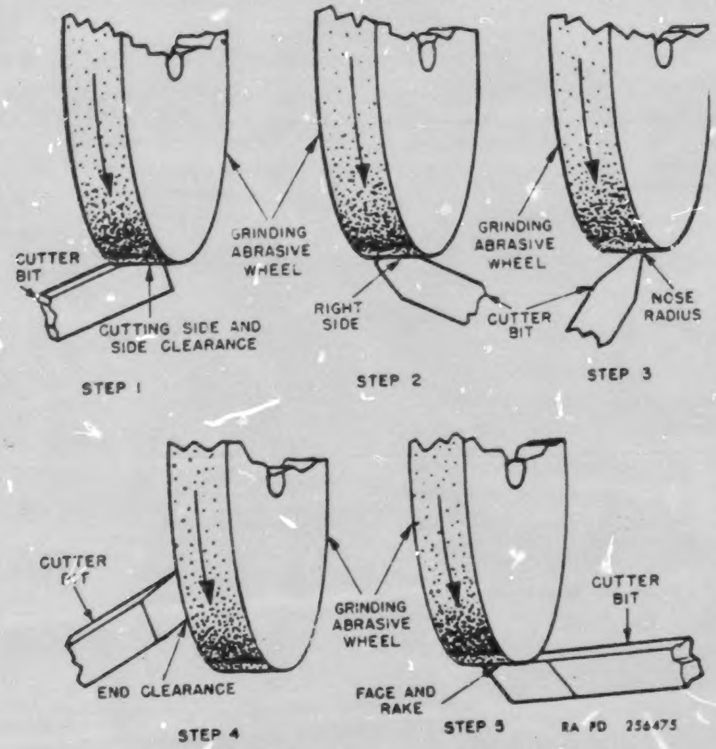

CUTTER BIT
CUTTING SIDE AND SIDE CLEARANCE
STEP 1
GRINDING ABRASIVE WHEEL
RIGHT SIDE
STEP 2
GRINDING ABRASIVE WHEEL
CUTTER BIT
NOSE RADIUS
STEP 3
CUTTER BIT
END CLEARANCE
STEP 4
GRINDING ABRASIVE WHEEL
FACE AND RAKE
STEP 5
CUTTER BIT
RA PD 256475

Figure 12. Grinding a roundnose turning cutter bit.

(c) Grind the radius or rounding on the nose of the bit by holding it against the wheel and turning it from side to side (step 3, fig 12). The radius should be approximately 1/32 to 3/64 inch.

(d) Grind the end clearance by holding the bit against the side of the wheel at the correct angle (step 4, fig 12).

(e) Grind the face of the bit (step 5, fig 12), holding it at the correct angle to obtain the necessary back rake and side rake.

(f) After bits have been ground on a grinding abrasive wheel, they will produce better quality work and have longer life if the cutting edges are honed with an oilstone.

6. CUTTING TOOLHOLDERS.

a. General. Common cutter bits are generally made from standard sizes of bar stock to fit into a forged cutting toolholder which, in turn, is fastened to the toolpost of the lathe. Special tools such as the knurling tool and the thread cutting toolholder with cutter are furnished with their own special forged toolholders and therefore may be fastened directly to the toolpost of the lathe. Carbide-tipped cutter bits are generally unsuitable for mounting in forged toolholders and are fastened directly to the lathe toolpost (fig 13) or mounted in an open side toolpost to provide rigid support for the bit.

b. Straight-shank cutting toolholder (fig 14). The straight-shank cutting toolholder may be used to support roundnose turning cutter bits, right-hand and left-hand turning cutter bits, and thread cutter bits. The holder is made of forged steel and contains a hardened steel setscrew for locking the cutter bit in place.

c. Right- and left-hand cutting toolholder (fig 14). The right- and left-hand offset cutting toolholders are designed to support right-hand and left-hand facing cutter bits which require that the bit be supported at an angle to the workpiece axis. The holder has a setscrew for locking the cutter bit in place.

d. Straight parting cutting toolholder (fig 14). The straight parting cutting toolholder is a forged steelholder shaped to hold flat, thin sectioned parting tools which are used to separate pieces on the lathe.

e. Right- and left-hand offset parting cutting toolholder (fig 14). The right- and left-hand offset parting cutting toolholders are similar to the straight parting cutting toolholder but are designed to hold the parting cutter bit at an angle to the holder shank. The offset holder is generally used when the workpiece to be parted or the stationary parts of the lathe may interfere with the holder if the straight parting cutting toolholder is used. In either case, the compound rest of the lathe must be adjusted so that the parting cutter bit enters the workpiece at right angles to the workpiece axis.

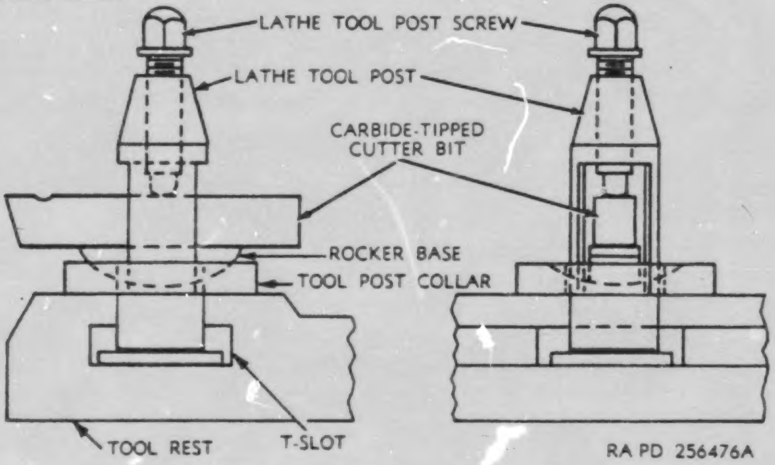


Figure 13. Carbide-tipped cutter bit mounted directly to tool post of lathe.

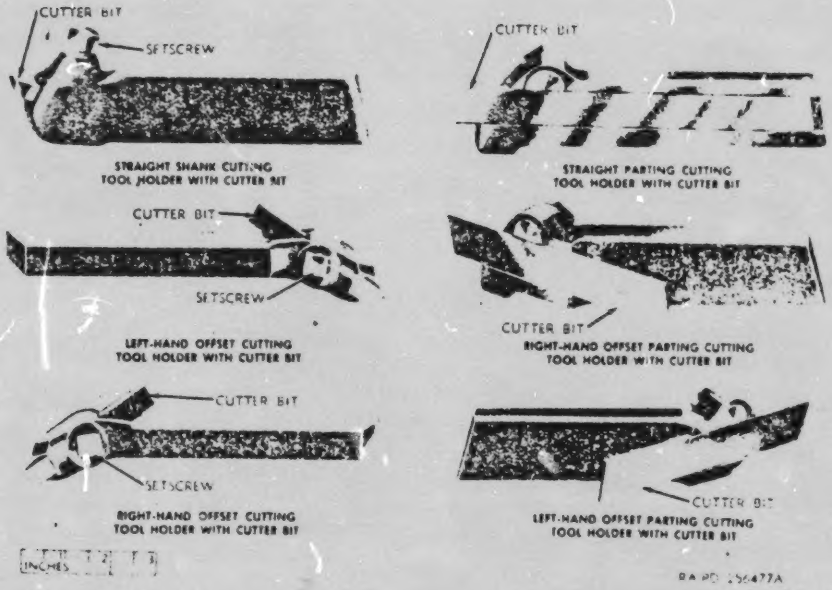

CUTTER BIT
SETSCREW
STRAIGHT SHANK CUTTING TOOL HOLDER WITH CUTTER BIT
CUTTER BIT
STRAIGHT PARTING CUTTING TOOL HOLDER WITH CUTTER BIT
CUTTER BIT
SETSCREW
LEFT-HAND OFFSET CUTTING TOOL HOLDER WITH CUTTER BIT
CUTTER BIT
RIGHT-HAND OFFSET PARTING CUTTING TOOL HOLDER WITH CUTTER BIT
CUTTER BIT
SETSCREW
RIGHT-HAND OFFSET CUTTING TOOL HOLDER WITH CUTTER BIT
CUTTER BIT
LEFT-HAND OFFSET PARTING CUTTING TOOL HOLDER WITH CUTTER BIT
INCHES

Figure 14. Types of cutting toolholders.

f. Boring bar cutting toolholder (fig 15). The boring bar cutting toolholder for the lathe comes in several commercial types, one of which is illustrated in figure 15. The boring bar cutting toolholder consists of three parts, the holder, the interchangeable end cap, and the boring tool bar. The boring tool bar is a rod with one end threaded to accept an end cap. Three end caps are supplied, each end cap slotted at different angles to accept a cutter bit. The standard angles are 30°, 45°, and 90°. Plain boring tool bars without end caps are often made to accept cutter bits at each end, one having a 90° slot, and the other end having a 45° slot. The holder is made of forged steel. It has a shank similar to that of the other cutting toolholders. The holder is secured to the lathe toolpost by the lathe toolpost screw. The boring tool bar is adjustable in the holder and can be locked in any desired position.

7. CHUCKS.

a. General. Workpieces are held to the headstock spindle of the lathe with chucks, faceplates, or lathe centers. A lathe chuck is a device that exerts pressure on the workpiece to hold it secure to the headstock spindle or tailstock spindle. Commonly used with the lathe are the independent chuck, the universal scroll chuck, the combination chuck, the drill chuck, the hollow headstock spindle chuck, the lathe tailstock chuck, the collet chuck, and the step chuck.

b. Independent chuck (fig 16).

(1) The independent chuck generally has four jaws which are adjusted individually on the chuck face by means of adjusting screws. The chuck face is scribed with concentric circles which are used for rough alinement of the jaws when chucking round workpieces. The final adjustment is made by turning the workpiece slowly and using gages to determine its concentricity. The jaws are the readjusted as necessary to aline the workpiece within very small tolerances.

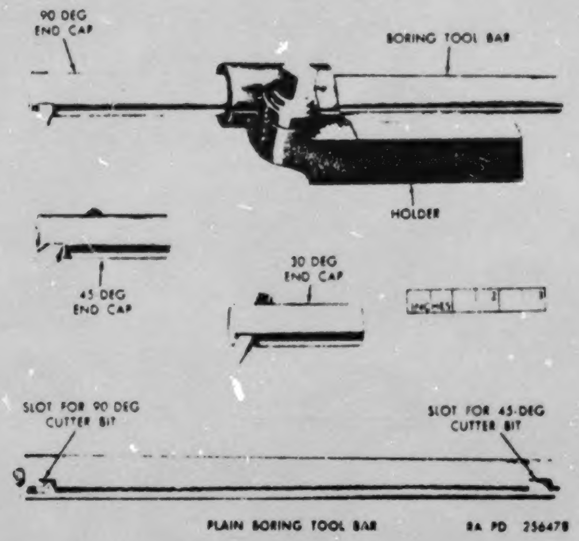

90 DEG END CAP
BORING TOOL BAR
HOLDER
45 DEG END CAP
30 DEG END CAP
INCHES 1 2 3
SLOT FOR 90 DEG CUTTER BIT
SLOT FOR 45-DEG CUTTER BIT
PLAIN BORING TOOL BAR
RA PD 256478

Figure 15. Boring bar cutting toolholder with end caps and cutter bits.

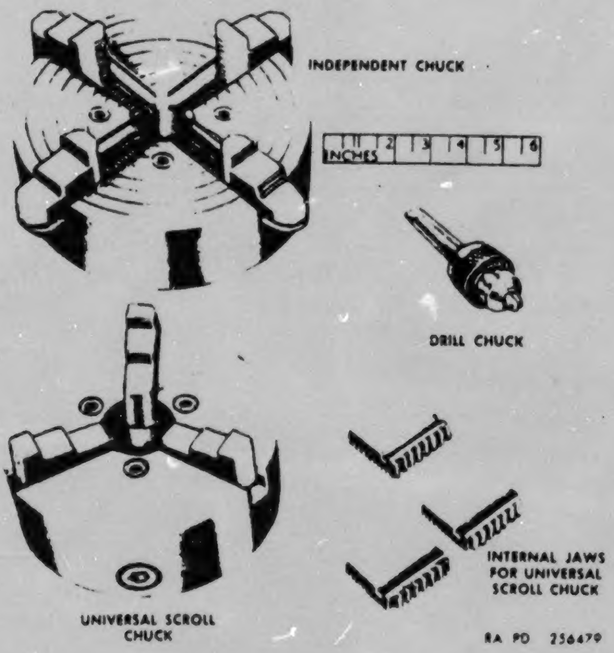

INDEPENDENT CHUCK
INCHES 1 2 3 4 5 6
DRILL CHUCK
INTERNAL JAWS FOR UNIVERSAL SCROLL CHUCK
UNIVERSAL SCROLL CHUCK
RA PD 256479

Figure 16. Independent chuck, universal scroll chuck, and drill chuck used with the lathe.

(2) The jaws of the independent chuck may be used as illustrated in figure 16 or may be reversed so that the steps face in the opposite direction; thus workpieces can be gripped either externally or internally. The independent chuck can be used to hold square, round, octagonal, or irregularly shaped workpieces in either a concentric or eccentric position due to the independent operation of each jaw.

(3) Because of its versatility and capacity for fine adjustment, the independent chuck is commonly used for mounting workpieces which must be held with extreme accuracy.

c. Universal scroll chuck (fig 16).

(1) The universal scroll chuck usually has three jaws which move in unison as an adjusting pinion is rotated. The advantage of the universal scroll chuck is its ease of operation in centering work for concentric turning. This chuck is not as accurate as the independent chuck, but when in good condition it will center work automatically within 0.003 inch of complete accuracy.

(2) The jaws are moved simultaneously within the chuck by means of a scroll or spiral threaded plate. The jaws are threaded to the scroll and move an equal distance inward or outward as the scroll is rotated by means of the adjusting pinion. Since the jaws are individually alined on the scroll, the jaws cannot be reversed. However, the chuck is usually supplied with two sets of jaws which can be interchanged.

(3) The universal scroll chuck can be used to hold and automatically center round or hexagonal workpieces. Having only three jaws, the chuck cannot be used effectively to hold square, octagonal, or irregular shapes.

d. Combination chuck. A combination chuck combines the features of the independent chuck and the universal scroll chuck and can have either three or four jaws. The jaws can be moved in unison on a scroll for automatic centering or can be moved individually if desired by separate adjusting screws.

e. Drill chuck (fig 16). The drill chuck is a small universal-type chuck which can be used in either the headstock spindle or in the tailstock for holding straight-shank drills, reamers, taps, or small diameter workpieces. The drill chuck has three or four hardened steel jaws which are moved together or apart by adjusting a tapered sleeve within which they are contained. The drill chuck is capable of centering tools and small diameter workpieces to within 0.002 or 0.003 inch when firmly tightened.

f. Hollow headstock spindle chuck (fig 17). The hollow headstock spindle chuck is similar to a drill chuck but is hollow and is provided with threads to screw onto the headstock spindle nose. This chuck can be used to hold rods, tubes, or bars which are passed through the headstock spindle. It is generally capable of centering workpieces to an accuracy of 0.002 inch.

g. Collet chuck.

(1) The collet chuck is the most accurate means of holding small workpieces in the lathe. The collet chuck consists of a spring machine collet (fig 18) and a collet attachment which secures and regulates the collet on the headstock spindle of the lathe.

(2) The spring machine collet (fig 18) is a thin metal bushing with an accurately machined bore and a tapered exterior. The collet has three lengthwise slots to permit its sides being sprung slightly inward to grip the workpiece. To grip the workpiece accurately, the collet must be no more than 0.001 inch larger or smaller than the diameter of the piece to be chucked. For this reason spring machine collets are generally supplied in sets with various capacities in 1/16-, 1/32-, or 1/64-inch increments. For general purposes, the spring machine collets are limited in capacity to 1 inch in diameter.

(3) The collet attachment which with the spring machine collet forms the collet chuck, consists of a collet sleeve, a drawbar, and a handwheel or hand lever to move the drawbar. Figure 19 illustrates a typical collet chuck installation. The collet sleeve is fitted to the right end of the headstock spindle. The drawbar passes through the headstock spindle and is threaded to the spring machine collet. When the drawbar is rotated by means of the handwheel, the collet is pulled inward and the collet walls are cammed together by contact with the collet sleeve, tightening the chuck to the workpiece.

(4) Collet chucks are usually standard equipment on toolroom-type engine lathes and on horizontal turret lathes. Spring machine collets are available in different shapes (fig 18) to chuck square and hexagonal workpieces of small dimensions as well as round workpieces.

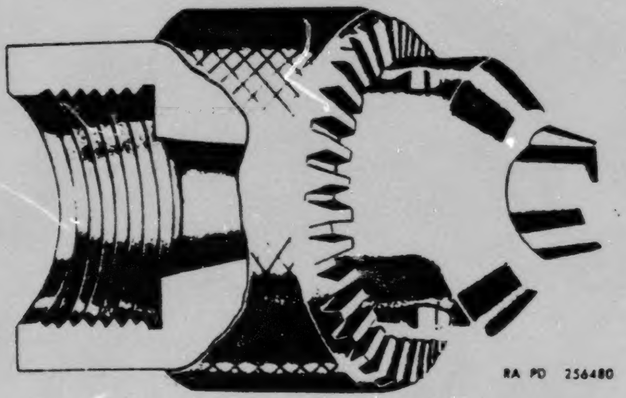


Figure 17. Hollow headstock spindle chuck.

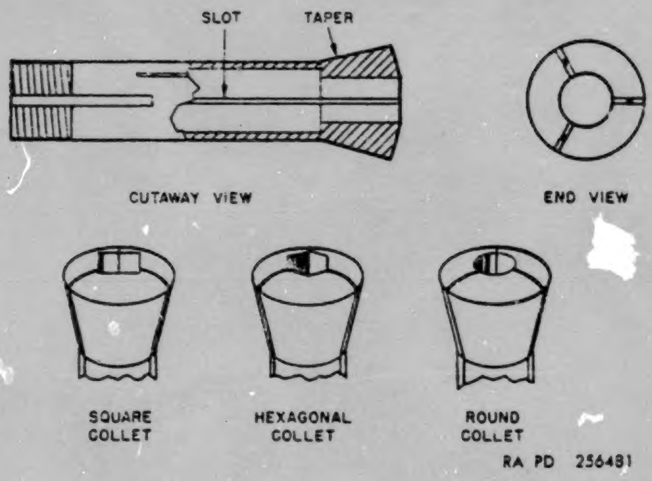

SLOT
TAPER
CUTAWAY VIEW
END VIEW
SQUARE COLLET
HEXAGONAL COLLET
ROUND COLLET
RA PD 256481

Figure 18. Spring machine collet shapes.

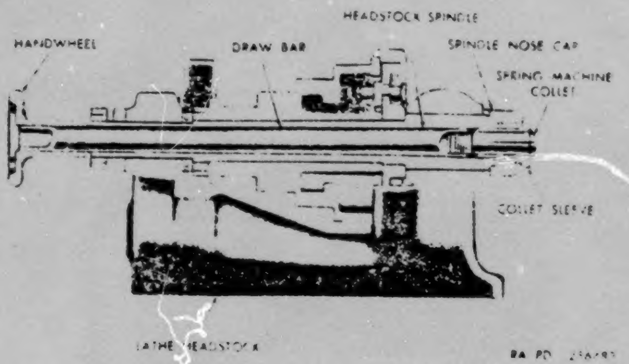

HEADSTOCK SPINDLE
HANDWHEEL
DRAW BAR
SPINDLE NOSE CAP
SPRING MACHINE COLLET
COLLET SLEEVE
LATHE HEADSTOCK
RA PD

Figure 19. Typical installation of collet chuck.

h. Step chuck. The step chuck is a variation of the collet chuck, but is intended for very accurate holding of workpieces larger than 1 inch in diameter. The step chuck consists of the handwheel or hand lever collet attachment (g above) and a step chuck machine collet (fig 20) in place of the regular spring machine collet. The step chuck machine collet, which is split into three sections like the spring machine collet, is threaded to the drawbar of the collet attachment. As the step chuck machine collet is drawn into the collet sleeve, the three sections of the collet are cammed against the workpiece by an inside taper in the collet sleeve. The step chuck is supplied in 2, 3, 4, and 5 inch sizes, the size indicating the maximum diameter of workpieces that can be supported. The step chuck machine collets are furnished blank and machined on the lathe to the desired step diameter.

i. Lathe tailstock chuck (fig 20). The lathe tailstock chuck is a device designed to support the ends of workpieces in the tailstock when a lathe center cannot be conveniently used. The chuck has a taper arbor that fits the lathe tailstock spindle. The three bronze self-centering jaws of the chuck will accurately close upon workpieces between 1/4 and 1 inch in diameter. The bronze jaws provide a good bearing surface for the workpiece. The jaws are adjusted to the diameter of the workpiece and then locked in place.

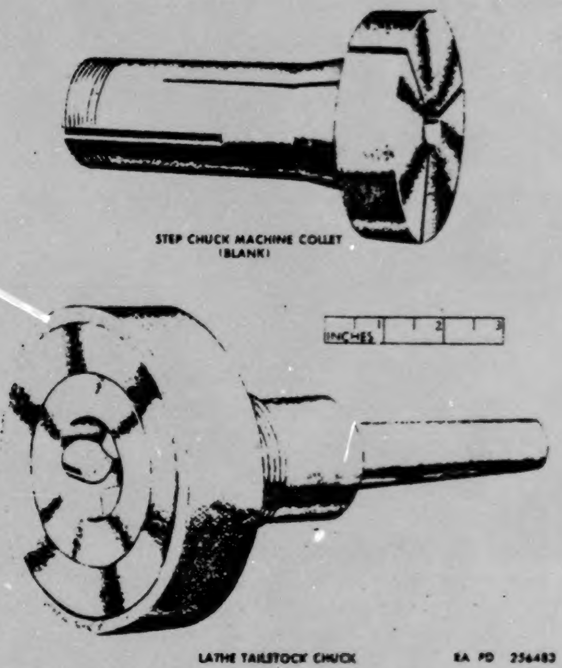


Figure 20. Step chuck machine collet and lathe tailstock chuck.

8. LATHE FACEPLATES.

a. A lathe faceplate (fig 21) is a flat, round plate that threads to the headstock spindle of the lathe. The faceplate is used for irregularly-shaped workpieces that cannot be successfully held by chucks or mounted between centers. The workpiece is either attached to the faceplate using angle plates or brackets or bolted directly to the plate. Radial T-slots in the faceplate surface facilitate mounting of workpieces. The faceplate is valuable for mounting workpieces in which an eccentric hole or projection is to be machined. The number of applications of the faceplates depend upon the ingenuity of the machinist.

b. A small faceplate known as a driving faceplate is used to drive the lathe dog for workpieces mounted between centers. The driving faceplate usually has fewer T-slots than the larger faceplates. When the workpiece is supported between centers, a lathe dog is fastened to the workpiece and engaged in a slot of the driving faceplate.

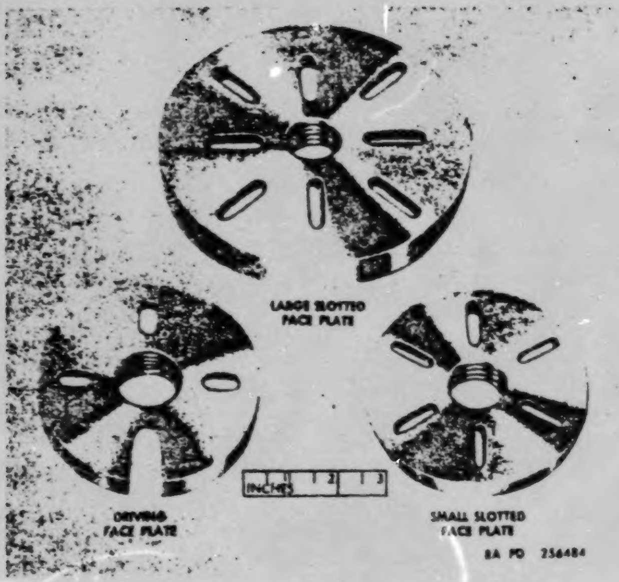


Figure 21. Lathe faceplates.

9. LATHE CENTERS.

a. General. Lathe centers are the most common devices for supporting workpieces in the lathe. Most lathe centers have a tapered point with a 60° included angle to fit workpiece holes with the same angle. The workpiece is supported between two centers, one in the headstock spindle and one in the tailstock spindle. Centers for lathe work have standard tapered shanks that fit into the tailstock directly and into the headstock spindle, using a center sleeve to convert the larger bore of the spindle to the smaller taper size of the lathe center. The centers are referred to as live centers or dead centers depending upon whether they move with the workpiece or remain stationary. The most common types of centers are described in b through f below.

b. Male center (fig 22). The male center or plain center is the type used in pairs for most general lathe turning operations. The point is ground to a 60° cone angle. When used in the headstock spindle, where it revolves with the workpiece, it is commonly called a live center. When used in the tailstock spindle, where it remains stationary when the workpiece is turned, it is called a dead center. Dead centers are always hard and must be lubricated very often to prevent overheating.

c. Pipe center (fig 22). The pipe center is similar to the male center but its cone is ground to a greater angle and is larger in size. It is used for holding pipe and tubing in the lathe.

d. Female center (fig 22). The female center is conically bored at the tip and is used to support workpieces that are pointed on the end.

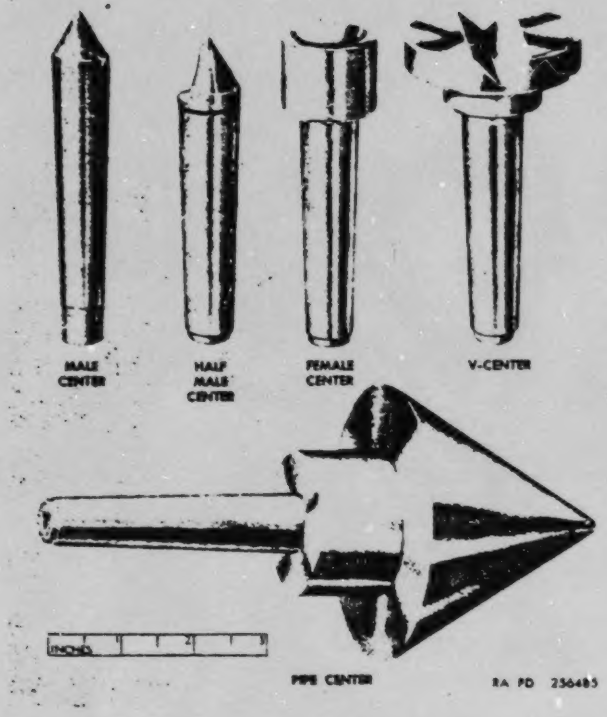


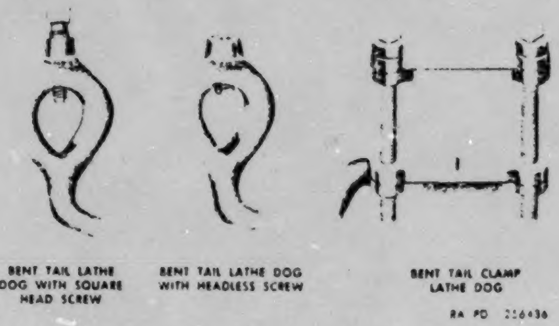
Figure 22. Types of lathe centers.

e. Half male center (fig 22). The half male center is a male center that has a portion of the 60° cone cut away. The half male center is used as a deadcenter in the tailstock where complete facing is to be performed. The cutaway portion of the center faces the cutting tool and provides the necessary clearance for the tool when facing the surface immediately around the drilled center in the workpiece.

f. V-center (fig 22). The V-center is used to support round workpieces at right angles to the lathe axis for special operations such as drilling or reaming.

10. LATHE DOGS.

a. Purpose. Lathe dogs (fig 23) are cast metal devices used to provide a firm connection between the headstock spindle and the workpiece mounted between centers. This firm connection permits the workpiece to be driven at the same speed as the spindle under the strain of cutting. Three common types of the lathe dogs are illustrated in figure 23. Lathe dogs may have bent tails or straight tails. When bent tail dogs are used, the tail fits into a slot of the driving faceplate. When straight tail dogs are used, the tail bears against a stud projecting from the faceplate.


BENT TAIL LATHE DOG WITH SQUARE HEAD SCREW
BENT TAIL LATHE DOG WITH HEADLESS SCREW
BENT TAIL CLAMP LATHE DOG

RA PD 216436

Figure 23. Common types of lathe dogs.

b. Safety. The bent tail lathe dog with headless setscrew is considered safer than the dog with the square head screw because the headless setscrew reduces the danger of the dog catching in the operator's clothing and causing an accident.

c. Special lathe dog. The bent tail clamp lathe dog is used primarily for holding rectangular workpieces.

11. MANDRELS.

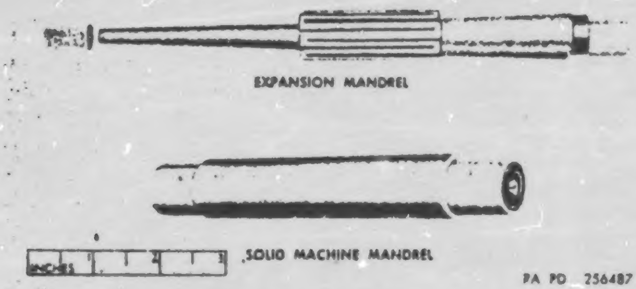
a. General. A workpiece which cannot be held between centers because its axis has been drilled or bored and which is not suitable for holding in a chuck or against a faceplate is usually machined on a mandrel. A mandrel is a tapered axle pressed into the bore of the workpiece to support it between centers. A mandrel should not be confused with an arbor which is a similar device but used for holding tools rather than workpieces.

b. Solid machine mandrel (fig 24). A solid machine mandrel is generally made from hardened steel and ground to a slight taper of from 0.0005 to 0.0006 inch per inch. It has very accurately countersunk centers at each end for mounting between centers. The ends of the mandrel are smaller than the body and have machined flats for the lathe dog to grip. The size of the solid machine mandrel is always stamped on the large end of the taper.

c. Expansion mandrel (fig 24). Since solid machine mandrels have a very slight taper, they are limited to workpieces with specific inside diameters. An expansion mandrel will accept workpieces having a greater range of sizes. The expansion mandrel is, in effect, a chuck arranged so that the grips can be forced outward against the interior of the hole in the workpiece.

12. RESTS.

a. General. Workpieces often need extra support, especially long, thin workpieces that tend to spring away from the cutter bit. Two common supports or rests are the steady rest and the follower rest.

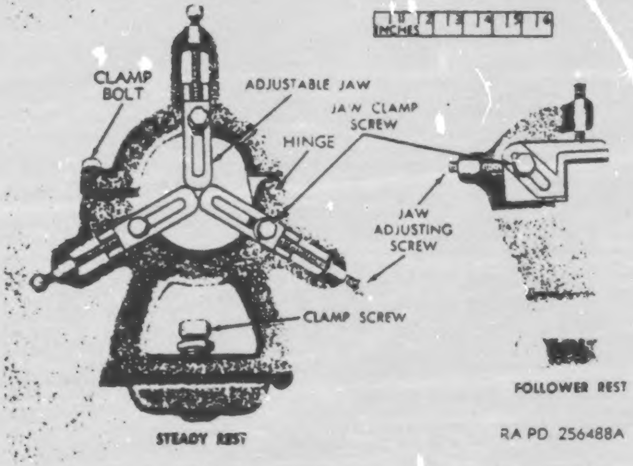

EXPANSION MANDREL
INCHES
SOLID MACHINE MANDREL

PA PD 256487

Figure 24. Types of mandrels.

b. Steady rest (fig 25). The steady rest, or center rest, as it is also called, is used to support long workpieces for turning and boring operations. It is also used for internal threading operations where the workpiece projects a considerable distance from the chuck or faceplate. The steady rest is clamped to the lathe bed at the desired location and supports the workpiece within three adjustable jaws. The workpiece must be machined with a concentric bearing surface at the point where the steady rest is to be applied. The jaws must be carefully adjusted for proper alinement and locked in position. The area of contact must be lubricated frequently. The top section of the steady rest swings away from the bottom section to permit removal of the workpiece without disturbing the jaw setting.

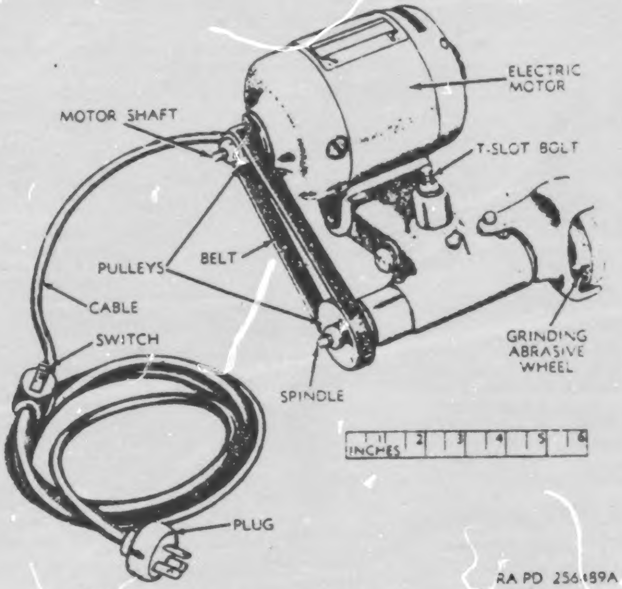
c. Follower rest (fig 25). The follower rest has one or two jaws that bear against the workpiece. The rest is fastened to the lathe carriage so that it will follow the cutter bit and bear upon the portion of the workpiece that has just been turned. The cut must first be started and continued for a short longitudinal distance before the follower-rest may be applied. The rest is generally used only for straight turning and for threading of long, thin workpieces.


INCHES
CLAMP BOLT
ADJUSTABLE JAW
JAW CLAMP SCREW
HINGE
JAW ADJUSTING SCREW
CLAMP SCREW
FOLLOWER REST
STEADY REST

RA PD 256488A

Figure 25. Steady and follower rests.

13. TOOLPOST GRINDING MACHINE. The toolpost grinding machine (fig 26) is a machine tool attachment specially designed for cylindrical grinding operations on the lathe. It consists primarily of a 1/4- or 1/3-horsepower electric motor and a wheel spindle connected by means of pulleys and a belt. The machine fastens to the compound rest of the lathe with a T-slot bolt which fits in the T-slot of the compound rest in the same manner as the lathe toolpost. The toolpost grinding machine mounts grinding abrasive wheels ranging from 1/4 to 3 or 4 inches in diameter for internal and external grinding operations, and the pulleys on the wheel spindle and motor shaft are interchangeable to provide proper cutting speeds for the various wheel sizes. The larger grinding abrasive wheels used for external grinding are attached to the wheel spindle with an arbor. Small, mounted grinding abrasive wheels for internal grinding are fixed in a chuck which screws to the wheel spindle. The electric motor is connected to an electrical power source by means of a cable and plug. A switch is usually provided at the attachment to facilitate starting and stopping of the motor.



RA PD 256489A

Figure 26. Toolpost grinding machine.

14. MILLING AND GRINDING LATHE ATTACHMENT. The milling and grinding lathe attachment (fig 27) is a versatile, self-powered attachment that fits to the carriage of the lathe. The attachment is used for milling slots, flats, or keyways on lathe mounted workpieces, for performing internal and external grinding operations, for drilling holes in the periphery of lathe mounted workpieces, for reaming and boring operations, and for milling gear teeth and square tooth threads. The spindle of the milling and grinding lathe attachment is vertically adjustable, riding on four shafts and controlled by a screw and handwheel. Different head accessories adapt the attachment for performing the variety of functions mentioned above.

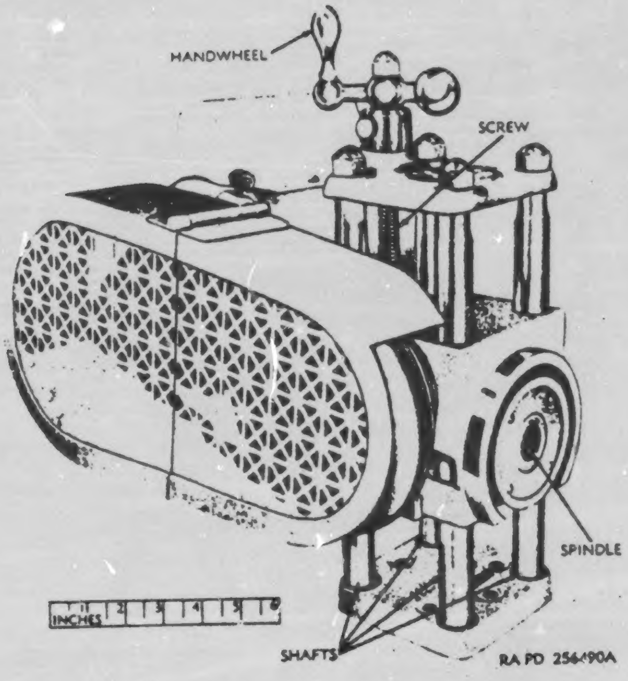


Figure 27. Milling and grinding lathe attachment.

15. LAYING OUT WORK.

a. General. Laying out work for the lathe consists primarily of determining the best method for supporting the workpiece in the lathe and then locating and preparing centers if necessary.

b. Methods for supporting workpieces. If the workpiece is to be turned or threaded and is reasonably small in diameter and reasonably long, the usual method of mounting is between centers. If extensive facing, boring, or internal threading is to be done, the usual method of mounting is in a chuck; and if the piece is very long, a steady rest should be used near the end to be worked. If the workpiece to be machined is irregular in shape and not easily adaptable to chucking, the workpiece is usually fastened to a faceplate.

c. Locating centers of cylindrical workpieces. If the workpiece is to be mounted between lathe centers in the headstock and tailstock, it is necessary to locate the centers of the workpiece accurately. Accurate centering is important so that the entire diameter will finish to size, and the depth of cut will be uniform throughout. Several methods of centering bar stock are described in (1) through (3) below.

(1) Hermaphrodite caliper method (fig 28). Set a pair of hermaphrodite calipers to approximately one-half the workpiece diameter and scribe four short arcs. The arcs will enclose the center.

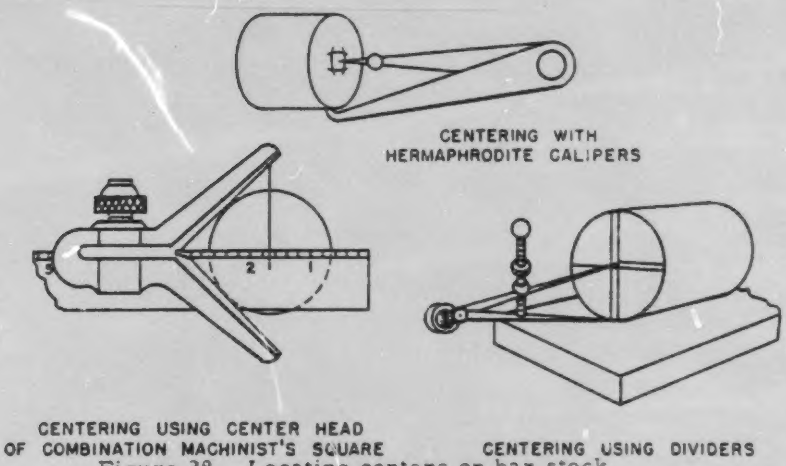


Figure 28. Locating centers on bar stock. RA PD 256491A

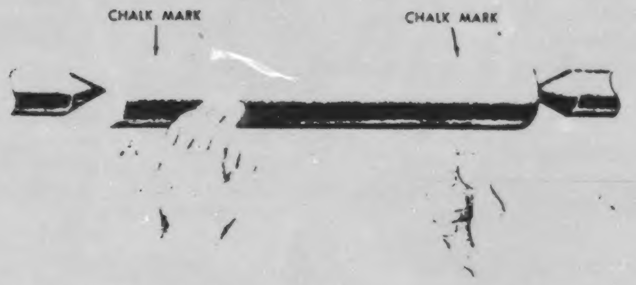
Note.—To make the scribed lines visible, the surface may be first lightly covered with pigment such as red lead or Prussian blue, or it may be treated with a light application of copper sulfate solution.

(2) Center head method (fig 28). Hold the center head of a combination machinist's square firmly against the workpiece and scribe a line close to the blade. Give the workpiece a quarter turn and scribe a similar line. The point at which the lines intersect will be the center.

(3) Divider method (fig 28). With the workpiece on a flat surface, set the dividers to approximately one-half the diameter of the piece and scribe four lines across each end. The center will be within the small square thus formed.

d. Locating centers of irregular workpieces. No definite rules can be given for centering irregular workpieces. Common sense, good judgment, and some layout experience are required if the centers are to be located correctly.

e. Testing centers. When the centers are accurately located, they should be tested before drilling and countersinking. Carefully indent the centers lightly with a center punch. Place the workpiece in the lathe between lathe centers. Hold a piece of chalk lightly against the workpiece and, supporting the chalk well, rotate the workpiece slowly by hand (fig 29). High spots can be clearly marked in this manner at either end of the piece, and the centers can be corrected as necessary. If it is necessary to change the center marks after testing, a satisfactory method of doing so is to support the piece in a vise and, holding a center punch at an angle, drive the center mark in the desired direction.

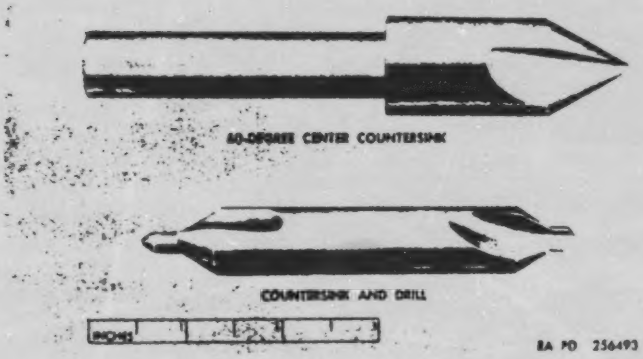


RA PD 256492

Figure 29. Method of testing location of centers.

f. Drilling and countersinking center holes.

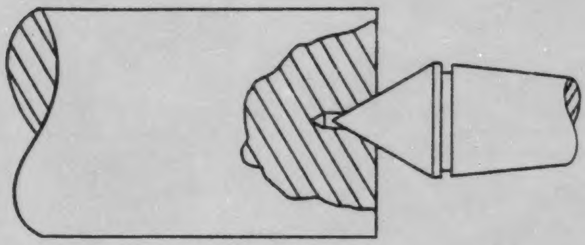
(1) After the centers have been properly located on the ends of the workpiece, drill and countersink centers to the proper depth and shape to fit the lathe centers. This can be done using a small twist drill followed by a 60° center countersink (fig 30) or, more commonly, using a countersink and drill which combines both tools (fig 30).



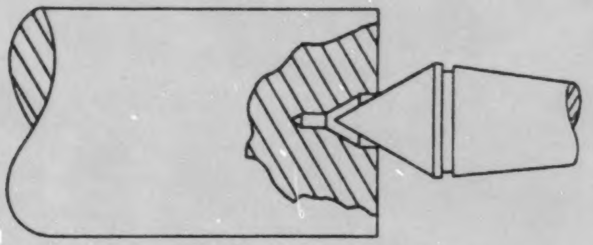
RA PD 256493

Figure 30. Tools for drilling and countersinking center holes.

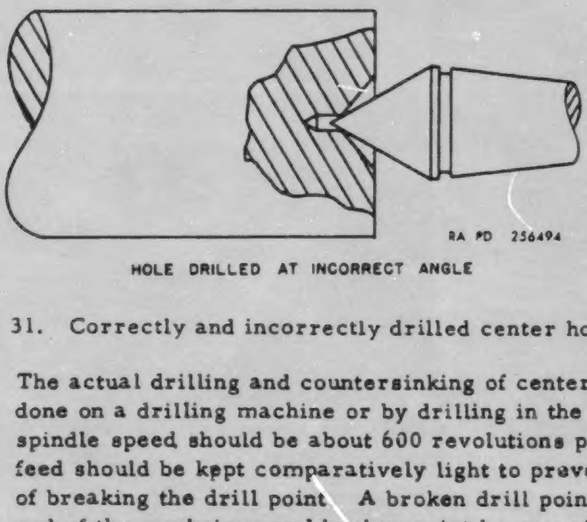
(2) It is very important that the center holes are drilled and countersunk so that they will fit the lathe centers exactly. Incorrectly drilled holes will subject the lathe centers to unnecessary wear, and the workpiece will not run true because of poor bearing surfaces. A correctly drilled and countersunk hole has a uniform 60° taper and has clearance at the bottom for the point of the lathe center. Figure 31 illustrates correctly and incorrectly drilled center holes. The holes should have a polished appearance so not to score the lathe centers.



CORRECTLY DRILLED HOLE



HOLE DRILLED TOO DEEP



HOLE DRILLED AT INCORRECT ANGLE

Figure 31. Correctly and incorrectly drilled center holes.

(3) The actual drilling and countersinking of center holes can be done on a drilling machine or by drilling in the lathe itself. The spindle speed should be about 600 revolutions per minute and the feed should be kept comparatively light to prevent any possibility of breaking the drill point. A broken drill point requires that the end of the workpiece and broken point be annealed so that the point can be drilled out. This procedure is slow and might result in spoiling of the workpiece. When drilling and countersinking the center holes, make allowance for the thickness of metal that will be removed by facing; failure to do so may result in insufficient bearing surface for the lathe center after the facing operation is accomplished.

(4) The suggested drill sizes for 1/2- and 2-inch diameter workpieces are 0.043 and 0.157 inch, respectively. The suggested countersink diameters for 1/2- and 2-inch diameter workpieces are 1/8 and 7/16 inch respectively.

16. MOUNTING WORKPIECE BETWEEN CENTERS.

a. Inserting and removing lathe centers. The quality of workmanship depends as much on the condition of the lathe centers as on the proper drilling of the center holes. Before mounting lathe centers in the headstock or tailstock, thoroughly clean the centers, the center sleeve, and the tapered sockets in the headstock and tailstock spindles. Any dirt or chips on the centers or in their sockets will prevent the centers from seating properly, and will cause the centers to run out of true.

(1) Install the lathe center in the tailstock spindle with a light twisting motion to insure a clean fit. Install the center sleeve into the headstock spindle and install the lathe center into the center sleeve with a light twisting motion.

Note. - When male centers are supplied in pairs, the tailstock center is usually distinguished from the headstock center by a groove close to the tapered point. This groove indicates that the tailstock center has been hardened and tempered for use as a deadcenter. The ungrooved headstock center is not hardened because it will rotate with the work as a live center.

(2) Remove the center from the headstock spindle by holding the pointed end with a cloth or rag in one hand and giving the center a sharp tap with a rod or knockout bar inserted through the hollow headstock spindle.

(3) Remove the center from the tailstock by turning the tailstock handwheel to draw the tailstock spindle into the tailstock. The center will contact the tailstock screw and will be bumped loose from the socket.

b. Grinding lathe centers (fig 32). Occasionally, it will be necessary to grind or redress the lathe centers when they become scored, misalined, or worn. The grinding is accomplished in the following manner:

(1) Carefully clean the spindle taper socket, lathe center, and center sleeve. Inspect these mating parts carefully and see that they are free from burs and scoring.

(2) Insert the lathe center and center sleeve solidly in the headstock spindle.

(3) Set the compound rest at an angle of 30° to the axis of the lathe.

(4) Clean and lubricate the dovetail slide upon which the compound rest moves. Adjust the tapered gib at the side of the compound rest to remove all looseness without causing the rest to bind.

(5) Cover the carriage and ways with paper or cloth to protect them from particles of abrasive grit from the grinding abrasive wheel. This step is important, for the grit could become imbedded and quickly destroy the accuracy of the lathe.

(6) Mount a toolpost grinding machine in the T-slot of the compound rest. Adjust the face of the grinding abrasive wheel parallel to the conical surface of the center. See that the point of the lathe center is alined with the center hole in the end of the arbor which retains the grinding abrasive wheel on the wheel spindle. Check the grinding machine for end play and adjust if necessary. True the grinding abrasive wheel.

(7) Set the compound rest near the center of its travel and move the carriage and crossfeed to position the grinding abrasive wheel within a few thousandths of an inch from the lathe center. Lock the carriage in this position to prevent movement during the grinding operation.

(8) Start lathe at moderate speed (60 to 100 f.p.m.) and then start the grinding machine, making sure that the lathe and grinding abrasive wheel both rotate in the same direction (the workpiece and the wheel will be moving in opposite directions at the point of contact).

Note. —Generally the lathe will be placed in reverse gear.

(9) Move the grinding abrasive wheel until it touches the rotating lathe center. Set depth of cut between 0.001 and 0.002 inch. Carefully feed the grinding abrasive wheel along the face of the lathe center by turning compound rest feed handle, starting at the point of the lathe center, and feeding toward the headstock. Make additional passes in the same direction, increasing the feed with each pass until the center is true and smooth.

(10) Stop the lathe and grinding machine and use a 60° angle center gage to check the center for accuracy. If the angle is not a true 60°, readjust the compound rest and repeat (8) and (9) above.

(11) Polish the center with a strip of fine emery cloth after grinding. Use a high spindle speed. It is good practice to grind the tailstock center first and grind the headstock center last so that the headstock center need not be removed from the lathe after grinding. This practice will give the headstock spindle more accuracy. Sharp points of centers should be removed to prevent personnel injury.

c. Checking alinement of centers.

(1) In order to turn a shaft straight and true between centers, it is necessary that the centers be in a plane parallel to the ways of the lathe. The tailstock may be moved laterally to accomplish this alinement by means of adjusting screws after it has been

released from the ways. Two zero lines are located at the rear of the tailstock and the centers are approximately alined when these lines coincide (fig 33). This alinement may be checked by moving the tailstock up close to the headstock so that the centers almost touch, and observing their relative positions (fig 33).

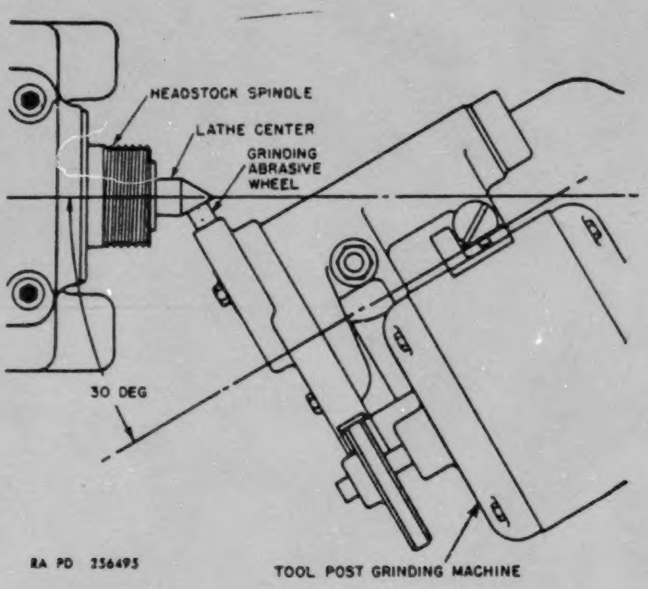


Figure 32. Grinding lathe centers with a toolpost grinding machine.

(2) The preferred method of checking alinement of centers is by mounting the workpiece between centers and taking light cuts at both ends without changing the carriage adjustments. Measure each end thus cut with calipers or a micrometer. If the tailstock end is greater in diameter than the headstock end, the tailstock is displaced to the rear, and if the tailstock end is smaller in diameter than the headstock end, the tailstock is dispersed to the front. Take additional cuts in the same manner after each adjustment until both cuts measure the same.

(3) Another good method of checking alinement of centers may be obtained by mounting a test bar (one in which the uniformity of the diameter is known) between the centers and bringing both ends of the bar to a zero reading on a dial indicator clamped to the lathe toolpost (fig 33). The tailstock must be clamped firmly to the bedways and the test bar must be firmly set between the centers when taking the indicator readings.

d. Setting up workpieces between centers.

(1) After the lathe centers have been properly installed and alined, and the workpiece correctly drilled and countersunk, mount the piece in the lathe using a driving faceplate and a lathe dog (fig 34).

(2) Make sure that the external threads of the headstock spindle are clean before screwing on the driving faceplate. Screw the faceplate securely onto the spindle. Clamp the lathe dog on the workpiece so that its tail overhangs the end of the workpiece. If the workpiece is finished, place a split ring of soft material such as brass between the setscrew of the dog and workpiece. Mount the workpiece between the centers. Make sure that the lathe dog tail fits freely in the slot of the faceplate and does not bind.

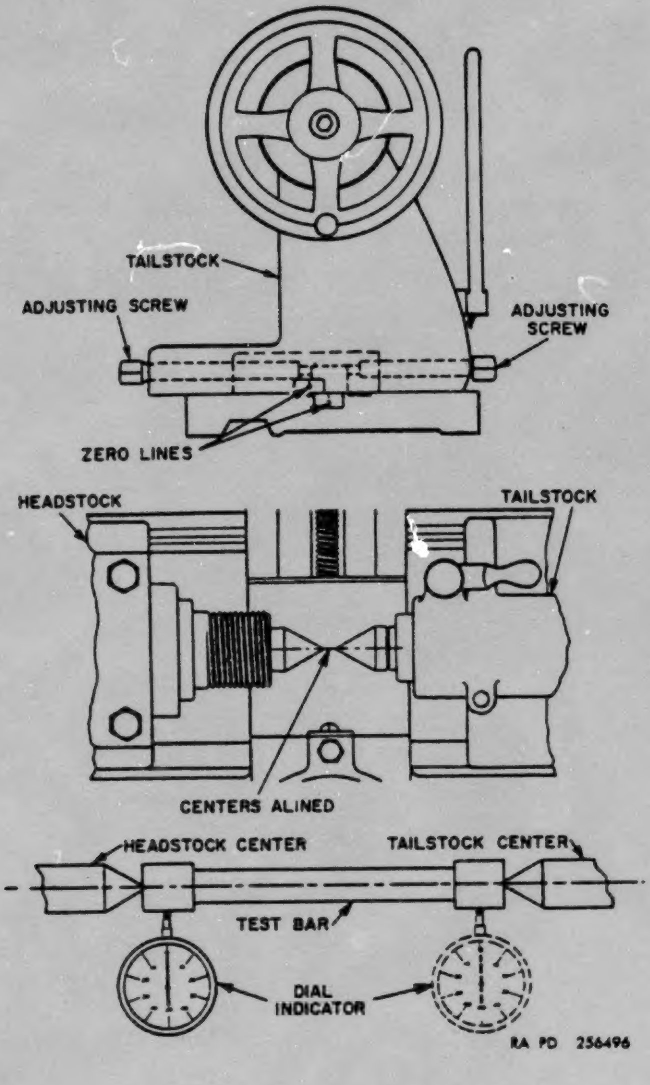

TAILSTOCK
ADJUSTING SCREW
ADJUSTING SCREW
ZERO LINES
HEADSTOCK
TAILSTOCK
CENTERS ALINED
HEADSTOCK CENTER
TAILSTOCK CENTER
TEST BAR
DIAL INDICATOR
RA PD 256496

Figure 33. Alinement of lathe centers.

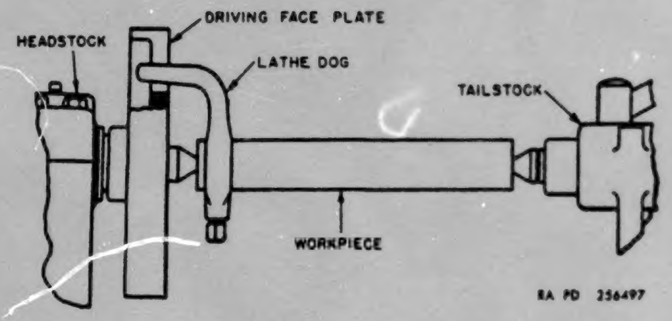


Figure 34. Work correctly mounted between centers in lathe.

(3) Since the tailstock center is a dead center and does not revolve with the workpiece, it requires lubrication. A few drops of oil mixed with white lead should be applied to the center before the workpiece is set up. The tailstock should be adjusted so that the dead center fits firmly into the center hole of the workpiece but does not bind. The lathe should be stopped at intervals and additional oil and white lead mixture applied to the dead center to prevent overheating and harm to the center and the workpiece.

17. MOUNTING WORKPIECES IN CHUCKS.

a. Installing the chuck. When installing the chuck or any attachment that screws onto the lathe headstock spindle, the threads and bearing surfaces of both spindle and chuck must be cleaned and oiled. In cleaning the internal threads of the chuck, a spring thread cleaner is very useful. Thread the chuck firmly on the headstock spindle by holding the chuck stationary and slowly rotating the lathe spindle by hand.

b. Mounting and alining workpieces in the independent chuck.

(1) Place the workpiece between the chuck jaws and adjust the jaws to an approximate centered position by referring to the concentric rings scribed on the chuck face.

(2) Start the lathe and hold a piece of chalk lightly against the revolving workpiece until a mark shows on the workpiece. Readjust the chuck by loosening the jaw or jaws opposite the chalk mark and tightening the jaw or jaws on the chalk mark side. Repeat the above process until the workpiece is satisfactorily alined.

(3) To center a workpiece having a smooth surface, the best method is to use a dial test indicator. Place the point of the indicator against the outside or inside diameter of the workpiece (fig 35). Revolve the workpiece slowly by hand and notice any deviations on the dial. This method will indicate any inaccuracy of the centering in thousandths of an inch. Test the face of the workpiece for wobble with a dial test indicator against the face of the piece (fig 36).

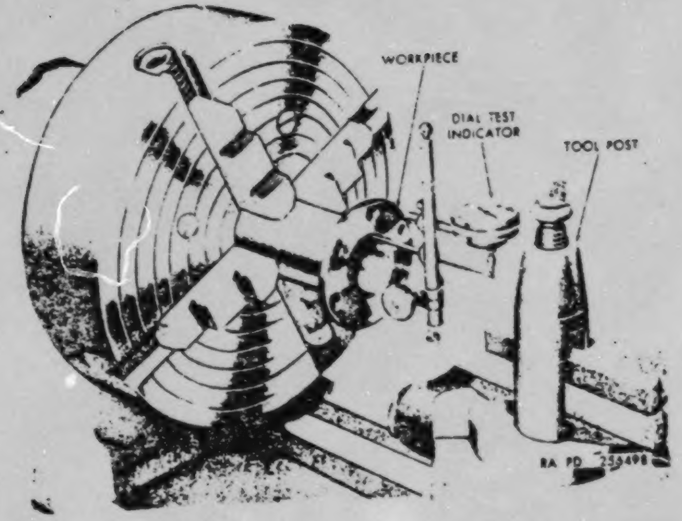

WORKPIECE
DIAL TEST INDICATOR
TOOL POST
RA PD 256498

Figure 35. Centering work with dial test indicator.

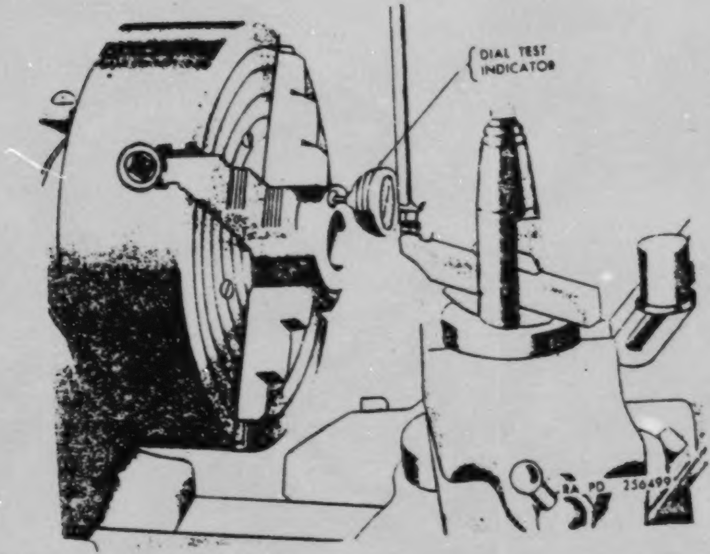

DIAL TEST INDICATOR
RA PD 256499

Figure 36. Testing face of workpiece for wobble.

(4) If an irregular shaped workpiece is mounted in the chuck, the alinement can be checked with a center indicator. Attach the center indicator to the lathe toolpost and place the short end of the indicator pointer in the center punchmark in the piece (fig 37). Move the tailstock center close to the long end of the indicator pointer, and adjust the toolpost so that the pointer is approximately in line with the tailstock center. Revolve the headstock spindle slowly by hand and observe any movement of the long end of the indicator pointer in relation to the tailstock center. The long end of the indicator will magnify any inaccuracy of centering; if it remains stationary, the workpiece is accurately centered.

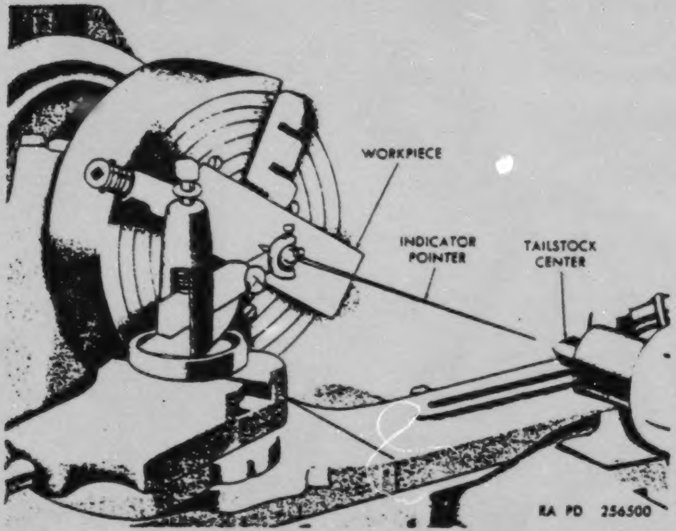


Figure 37. Using a center indicator to check workpiece alinement.

c. Setting workpiece in universal scroll chuck, hollow spindle chuck, or drill chuck. No satisfactory centering adjustments are possible with universal scroll chucks, hollow spindle chucks, and drill chucks; therefore, if the workpiece cannot be satisfactorily centered in one of these chucks, the independent chuck must be used (b above). To set up the workpiece in the universal scroll chuck, place the piece between the jaws and turn the adjusting pinion to bring the jaws firmly against the piece.

d. Removing chucks from the lathe. To remove chucks that are screwed to the headstock spindle of the lathe, a chuck-removing wrench should be used. If a wrench is unavailable, place a wooden block between the ways of the lathe and another wooden block between a way of the lathe and one chuck jaw (fig 38). Then, set lathe spindle in reverse and start in low gear to loosen chuck from spindle.

Caution.—A wooden plate should always be placed on the lathe bed before this operation to prevent the lathe bed or chuck from being damaged if the chuck should drop.

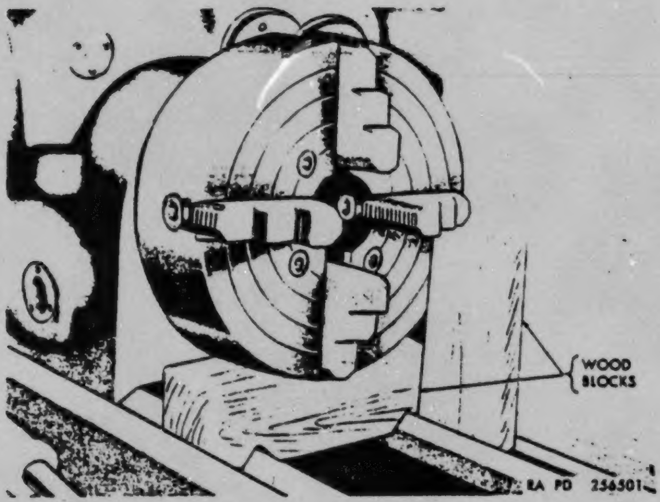


Figure 38. Removing chuck from lathe spindle by means of a wooden block.

18. MOUNTING WORKPIECES TO FACEPLATES.

a. Installing and alining the faceplate. When screwing the faceplate on the headstock spindle, the same cleaning and lubricating procedures described for chucks should be observed. The accuracy of the bearing surface of the faceplate is extremely important. Any unevenness of this surface should be removed by taking a facing cut.

b. Mounting workpiece to faceplate. The workpiece is attached to the faceplate by bolting angle plates and brackets to secure the workpiece. Care should be exercised when clamping the piece so that neither the piece nor the faceplate will be sprung. To eliminate any spring or vibration caused by having the piece offset on the faceplate, the balance weights may be used. Paper placed between the faceplate and the piece will help reduce possible slippage caused by slight unevennesses on the workpiece or faceplate. Figure 39 illustrates a typical setup using the faceplate.

c. Checking centering of workpiece on faceplate. The alinement or centering of a workpiece on faceplates should be checked by using a dial test indicator or a center indicator.

d. Removing faceplate from lathe. The faceplate should be removed from the lathe in the same manner described for removing chucks. If the wooden block method is used, bolt a projecting bracket or lug to the faceplate to grip the wooden block when the spindle is rotated.

19. MOUNTING WORKPIECES ON MANDRELS.

a. Selection. Make sure the mandrel selected is of the proper size for the workpiece to be mounted. The bore of the workpiece and the mandrel must be free of burs and both surfaces must be thoroughly clean.

where, r.p.m. = spindle speed (in revolutions per minute);
f.p.m. = cutting speed (in ft. per min.);
π = 3.1416;
D = diameter (in in.) of workpiece.

For example; if a 2.250-inch diameter workpiece is to be cut at the rate of 120 feet per minute, the spindle speed is calculated as follows:

$$\text{r.p.m.} = \frac{\text{f.p.m.}}{D} = \frac{12}{3.1416} \times \frac{120}{2.250} = 204 \text{ r.p.m.}$$

Spindle speed for drills and other rotating cutters can be determined using the same formula by substituting the cutting diameter of the drill or cutter for the diameter of the workpiece.

TABLE II. LATHE CUTTING SPEEDS FOR STRAIGHT TURNING AND THREADING

Material	Straight turning speed (f.p.m.)[1]	Threading speed (f.p.m.)[1]
Aluminum	200 to 300	50
Brass, yellow	150 to 200	50
Bronze, soft	80 to 100	30
Bronze, hard	30 to 80	20
Cast iron	50 to 80	25
Copper	60 to 80	25
Monel metal	100 to 120	35
Steel, high carbon (tool)	35 to 40	15
Steel, low carbon	80 to 100	35
Steel, medium carbon	60 to 80	25
Steel, stainless	40 to 50	15

[1] The speeds are based on the use of high-speed steel cutter bits. These speeds may be increased 25 to 50 percent if a cutting oil is used. If Stellite or carbide-tipped cutter bits are used, speeds may be 2 or 3 times as high as those given for high-speed steel cutter bits. If carbon-steel cutter bits are used, the speed should be reduced by about 25 percent.

(4) Other factors to consider when selecting cutting speed include use of cutting oil, length and diameter of the workpiece, and the condition of the lathe. If a large stream of proper cutting oil is applied to the workpiece at the cutter bit, the cutting speed can be increased. If the diameter of the workpiece is small and its length great enough to set up vibrations due to speed, a poor finish will result; to correct this condition, the speed must necessarily be reduced. The lathe may also be in poor condition so that high speeds will cause harmful vibrations.

(5) The technical manual for the lathe being used should be consulted for instructions in setting the spindle speed for operation. If a

desired spindle speed is not available on the lathe, select a speed nearest that which is desired, generally the first slower speed available. For efficient lathe operation, the machinist should be able to recognize too slow a speed as well as too fast a speed.

c. Feed.

(1) General. Feed is the term applied to the distance the cutter bit advances for each revolution of the workpiece. Feed is specified in inches per revolution. Since the best feed depends upon a number of factors such as depth of cut, type of material, size of workpiece, and condition of the lathe, it is difficult to list the best feed for different materials.

(2) Rough cuts. For rough cuts, the feed may be relatively heavy since the surface need not be exceptionally smooth. For most materials, the feed for rough cuts should be 0.010 to 0.020 inch per revolution. The feed may be 0.040 inch on large lathes with larger diameter workpieces. Care must be taken when turning slender workpieces as a heavy cut may bend the piece, ruining it. In this case, it is best to reduce the feed to 0.008 to 0.015 inch per revolution.

(3) Finish cuts. For finish cuts, a light feed is necessary since a heavy feed causes a built-up edge to form on the surface which produces a poor finish. If a large amount of stock is to be removed, it is advisable to take one or more roughing cuts ((2) above) and then take light finishing cuts at relatively high speeds. For most materials, the feed for finishing cuts should be 0.003 to 0.010 inch per revolution. An exception is the finishing of soft metals like aluminum where a broadnose cutter bit is used at feeds as great as 1/8 to 1/2 inch per revolution.

d. Depth of cut.

(1) General. The depth of cut regulates the reduction in diameter of the workpiece for each longitudinal traverse of the cutter bit. The workpiece diameter is reduced by twice the depth of cut in each complete traverse of the cutter bit. Generally, the deeper the cut, the slower the speed, since a deep cut requires more power.

(2) Rough cuts. The depth of cut for roughing is generally five to ten times deeper than the feed. The reason for this is that more of the cutting edge of the cutter bit is in contact with the workpiece for the amount of metal being removed and permits a greater speed to be used. For roughing with feeds of from 0.010 to 0.020 inch per revolution, the depth of cut should be between 3/16 and 1/4 inch. Deeper cuts up to 1/2 inch can be taken but the feed should be proportionately reduced. A heavy cut may cause the workpiece and cutter bit to chatter and in this case the depth of cut should be reduced.

(3) Finish cuts. Finish cuts are generally very light, and the cutting speed therefore can be increased since the chip is thin.

22. CUTTING OILS.

a. General. The chief purpose of a cutting oil is to cool the cutter bit and workpiece, and the name coolant is often given to the oil. A cutter bit will last longer and will be capable of withstanding greater speeds without overheating when a cutting oil is used. A cutting oil also helps lubricate cutter bits, improves the finish of the workpiece, guards against rusting, and washes away chips from the cutting area.

b. Use. In production operations, the practice is to flood the workpiece and cutter bit with cutting oil in order to obtain a full benefit of its use. For effective cooling, it is important that the oil be directed at the exact point of the cutter bit contact. A large stream at low velocity is to be preferred to a small stream at high velocity. In small shops where pump equipment is not available, cutting oils are used only for finishing and delicate operations. It is general practice in this case to apply the cutting oil only when actually required.

c. Types of cutting oils. Cutting oils most commonly used and their general applications are described in (1) through (7) below. Table III lists cutting oils for specific lathe operations for different materials to be machined.

(1) Lard oil. Pure lard oil is one of the oldest and best cutting oils. It is especially good for thread cutting, tapping, deep hole drilling, and reaming. Lard oil has a high degree of adhesion or oiliness, a relatively high specific heat, and its fluidity changes slightly with temperature. It is an excellent rust preventive and produces a smooth finish on the workpiece. Because lard oil is expensive, it is seldom used in a pure state but is combined with other ingredients to form good cutting oil mixtures.

(2) Mineral oil. Mineral oils are petroleum-base oils that range in viscosity from kerosene to light paraffin oils. Mineral oil is very stable and does not develop disagreeable odors like lard oil; however, it lacks some of the good qualities of lard oil such as adhesion, oiliness, and high specific heat. Because it is relatively inexpensive, it is commonly mixed with lard oil or other chemicals to provide cutting oils with desirable characteristics. Two mineral oils, kerosene and turpentine, are often used alone for machining aluminum and magnesium. Paraffin oil is used alone or with lard oil for machining copper and brass.

(3) Mineral-lard cutting oil mixture. Various mixtures of mineral oils and lard oil are used to make cutting oils which combine the good points of both ingredients but prove more economical and often as effective as pure lard oil.

(4) Sulfurized-fatty-mineral oil. Most good cutting oils contain mineral oil and lard oil with various amounts of sulfur and chlorine which give the oils good antiweld properties and promote free machining. These oils play an important part in present day machining because they provide good finishes on most materials and aid the cutting of tough material.

TABLE III. CUTTING OILS FOR LATHE OPERATIONS

Material	Cutting Oil		
	Heavy cutting	Light cutting	Threading
Aluminum	Dry; soluble cutting oil.	Dry.	Mineral-fatty-blend cutting oil.
Brass	Dry; soluble cutting oil.	Dry.	Sulfurized-fatty-mineral cutting oil.
Bronze	Soluble cutting oil.	Soluble cutting oil.	Sulfur-treated mineral-lard cutting oil.
Cast iron	Dry.	Dry.	Sulfurized-fatty-mineral cutting oil.
Copper	Dry; mineral-fatty-blend cutting oil.	Dry; mineral-fatty-blend cutting oil.	Mineral-fatty-blend cutting oil.
Monel metal	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Pure lard cutting oil; sulfurized-fatty-mineral cutting oil.
Steel, machine	Soluble cutting oil.	Mineral-fatty blend cutting oil; soluble cutting oil.	Sulfurized-fatty-mineral cutting oil.
Steel, tool	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Pure lard cutting oil; sulfurized-fatty-mineral cutting oil.
Steel, stainless	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Pure lard cutting oil; sulfurized-fatty-mineral cutting oil.

(5) Soluble cutting oils. Water is an excellent cooling medium but has little lubricating value and hastens rust and corrosion. Therefore mineral oils or lard oils which are miscible with water are often mixed with water to form a cutting oil. Soluble oil and water has lubricating qualities dependent upon the strength of the solution. Generally, soluble oil and water is used for rough cutting where quick dissipation of heat is most important. Borax and trisodium phosphate are sometimes added to the solution to improve its corrosion resistance.

(6) Soda water mixture. Salts such as soda ash and trisodium phosphate are sometimes added to water to help control rust. This mixture is the cheapest of all coolants and has practically no lubricating value. Lard oil and soap in small quantities are sometimes added to the mixture to improve its lubricating qualities. Generally, soda water is used only where cooling is the prime consideration and lubrication a secondary consideration. It is especially suitable in reaming and threading operations on cast iron where a better finish is desired.

(7) White lead and lard oil mixture. White lead can be mixed with either lard oil or mineral oil to form a cutting oil which is especially suitable for difficult machining of very hard metals.

23. FACING.

a. General. Facing is the square finishing of the ends of the workpiece and is often used to bring the piece to a specified length. In facing operations, the cutter bit does not traverse laterally (left or right) but cuts inward or outward from the axis of the piece. Facing of ends is usually performed before turning operations.

b. Mounting workpiece by facing. The workpiece to be faced may be mounted between centers or in a lathe chuck. If the right end of the piece is to be faced and the piece is to be mounted between centers, a half center is often used in the tailstock spindle. The half center permits complete facing to the center hole without interference with the center. With the piece mounted between centers, the left end cannot be faced if a lathe dog is used. It is advisable to reverse the piece for this operation.

c. Proper cutter bit for facing. The right-hand facing cutter bit (fig 8) is used for facing the right end of the workpiece and shoulders which face to the right. The left-hand facing cutter bit is used for facing the left end of the workpiece and shoulders which face to the left.

d. Position of the cutter bit for facing (fig 41). With the cutter bit positioned in the cutting toolholder, fasten the holder to the toolpost. Carefully adjust the holder so that the cutting edge of the bit is exactly on the horizontal centerline of the workpiece. If the cutting edge is not on center, the end cannot be faced to the center of the piece, and the rake and clearance angles will not be correct. Adjust the cutting edge of the bit to a slight angle to the workpiece surface by adjusting the compound rest of the lathe.

e. __Facing operation__. For the first or roughing cut, set the cutter bit (d above) and begin the cut as close as possible to the axis of the workpiece, feeding the bit outward, away from the axis (fig 41). Remove only enough metal to square the end over its entire surface. If the piece must be faced to a specified length, take two or more roughing cuts in the same manner, leaving a small amount of metal to be removed for the finishing cut. For the finishing cut, readjust the bit so that the cutting edge is set nearly flat against the workpiece surface, removing only a light, thin chip. The finishing cut can be taken in either direction, from the axis outward as in the roughing cut, or from the circumference of the workpiece inward toward the axis. In facing, care is needed to see that the bit does not contact the tailstock center.

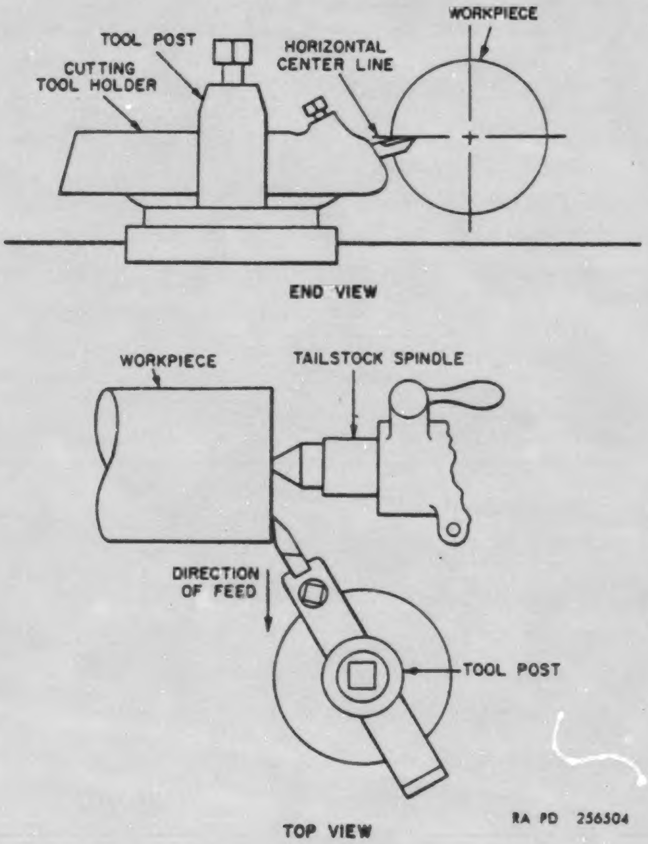

WORKPIECE
TOOL POST
HORIZONTAL CENTER LINE
CUTTING TOOL HOLDER
END VIEW
WORKPIECE
TAILSTOCK SPINDLE
DIRECTION OF FEED
TOOL POST
RA PD 256504
TOP VIEW

Figure 41. Position of the cutter bit for facing.

24. STRAIGHT TURNING.

a. General. Straight turning may be performed upon a workpiece supported in a chuck, but the majority of workpieces turned on an engine lathe are turned between lathe centers. Turning is the removal of metal from the external surface of cylindrical workpieces.

b. Mounting workpieces for straight turning. Lathe centers must be in good condition and carefully alined if the turning operation is to be accurate. If necessary, regrind the centers and check their alinement. When turning the workpiece, considerable heat will be generated which will cause the workpiece to expand. Lathe centers that are too tight may cause binding of the workpiece due to this expansion. The tailstock center or dead center must be well lubricated to prevent its overheating. The center hole and the tailstock center should be lubricated before the cutting operation with a mixture of white lead and oil. During the turning operation, feel the dead center frequently to determine whether lubrication or adjustment is necessary.

c. Proper cutter bits for straight turning. Straight turning is accomplished with the left-hand turning cutter bit, the right-hand turning cutter bit, or the roundnose turning cutter bit (fig 8). Wherever possible, the right-hand turning cutter bit or a roundnose bit ground for right to left turning is used and the bit is fed toward the headstock. If circumstances demand that the bit feed from left to right, such as in turning up to a shoulder, the left-hand cutter bit is used. The roundnose turning cutter bit is especially efficient for finishing cuts.

d. Position of cutter bit for straight turning. The cutter bit should be locked in the cutting toolholder and the holder should be fixed to the toolpost so that the cutting edge of the bit touches the workpiece surface at about 5° above the horizontal centerline of the piece (fig 42) since this position gives the bit a better cutting action. The distance above center is governed by the diameter of the workpiece and front clearance angle of the bit. In a horizontal plane, the bit and holder should be positioned at a right angle to the workpiece axis or at a slight leading angle so that the bit will not dig into the piece if the bit or toolholder should accidentally loosen on the toolpost.

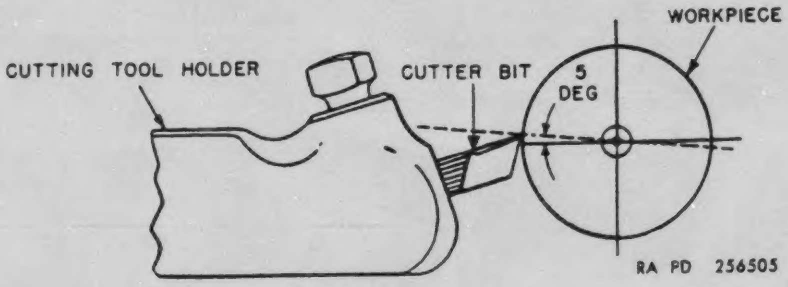


Figure 42. Position of cutter bit for straight turning.

OS 424, 8-P49

e. Straight turning operation. As a rule, the workpiece is turned down by a number of roughing cuts to a predetermined diameter which is within 1/32 to 1/64 inch of the diameter desired. The remaining metal is removed by a finish cut with a fine feed to produce a good surface. After taking the first roughing cut along the entire workpiece surface, check the center alinement by measuring each end with calipers. If the ends are of different diameters, the tailstock center is out of alinement with the headstock spindle and realinement is necessary. Continue cutting after alinement is effected, stopping the lathe at intervals to check the tailstock center (b above). After roughing, reverse the ends of the workpiece so that the area held by the lathe dog can be turned. When the piece is within 1/32 to 1/64 inch of the desired size, reduce the depth of cut, reduce the feed, increase the speed, and take light finishing cuts to the proper dimension. Caliper the piece after each cut, using micrometer calipers. Reverse the piece again and, using shims under the lathe dog to prevent scoring of the machined surface, finish the other end of the piece.

Note. —Remember that if the workpiece is turned smaller than the desired finished size, it cannot be made larger and is ruined.

25. SHOULDER TURNING.

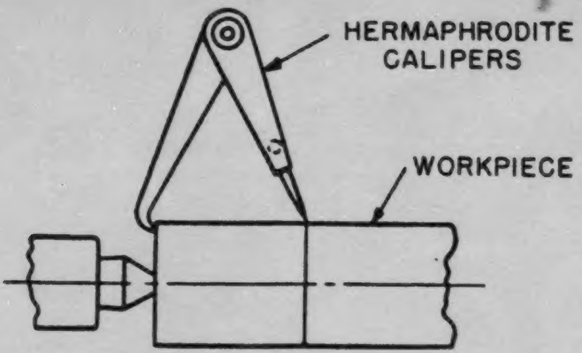
a. General. It is frequently necessary to turn a workpiece so that it will have two or more diameters in its length. For example, a bar 12 inches long might be 3 inches in diameter for half its length, and 3-1/2 inches in diameter for the other half. It would therefore have an abrupt step or shoulder 1/4 inch high 6 inches from the small end. The shoulder may be machined so that it forms a sharp corner with the small diameter, or a fillet may be formed so that the corner is slightly rounded instead of square.

b. Mounting workpiece for shoulder turning. The workpiece may be mounted in a chuck or between centers as for straight turning.

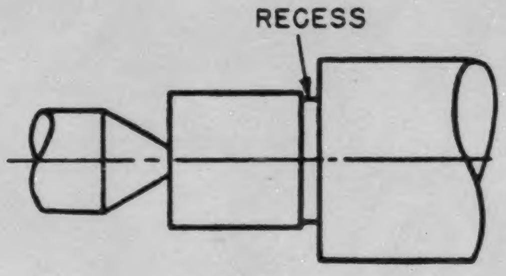
c. Proper cutter bits for shoulder turning. For turning the small diameter portion of the workpiece down to the desired size, a roundnose turning cutter bit (fig 8) is preferred. The shoulder is finish turned to size using a facing cutter bit (fig 8) if a square shoulder is required, or with a roundnose turning cutter bit if a fillet is required. The roundnose cutter bit may be specially ground to produce a special size fillet if necessary. A parting cutter bit (fig 8) may be used at the shoulder location to mark the position of the shoulder and in some cases to provide an undercut or recess (fig 43) if a bearing is to be carried on the shoulder.

d. Shoulder turning operation.

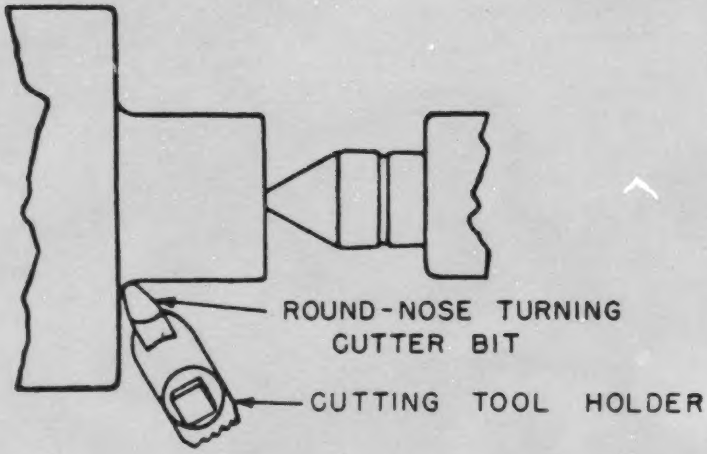
(1) The first important step in machining a shoulder is to locate the shoulder correctly. Usually, the position is marked by chalking the workpiece after it has been rough turned to the larger diameter and accurately indicating the shoulder location with hermaphrodite calipers (fig 43).


HERMAPHRODITE CALIPERS
WORKPIECE

LOCATING SHOULDER POSITION



UNDERCUT OR RECESSED SHOULDER FOR BEARING SEAT


ROUND-NOSE TURNING CUTTER BIT
CUTTING TOOL HOLDER

FORMING FILLET AT SHOULDER RA PD 256506

Figure 43. Location of shoulder position and types of shoulder formations.

(2) The small diameter portion of the workpiece is then turned down by a series of roughing cuts taken toward the shoulder. Take care to stop the traverse of the cutter bit about 1/32 inch before it reaches the scribed line; this 1/32 inch is important because it leaves sufficient metal on the shoulder to provide for facing operation after the smaller diameter portion has been turned to size.

(3) An alternate method of shoulder turning is to cut in at the shoulder mark with a parting cutter bit (fig 8). If this is done, be sure the bit does not cut deeper than the required small diameter for square finished shoulders or deeper than the small diameter less the radius of the intended fillet if a filleted shoulder is required. However, if the shoulder is to carry a bearing, it may be desirable that an undercut or recess be left to assure good fit (fig 43). The workpiece is then turned to size, stopping the traverse of the cutter bit at the recess.

(4) As in straight turning, the workpiece should be rough turned to within 1/32 to 1/64 inch of its finished diameter. The procedure described in (a) or (b) below should be followed for the finishing cut.

(a) Filleted shoulder finish. To finish a filleted shoulder, use longitudinal feed and turn the small diameter up to the shoulder with a roundnose turning cutter bit positioned as shown in figure 43. Engage the crossfeed and allow the bit to face the shoulder, moving outward from the axis.

(b) Squared shoulder finish. To finish a square shoulder, set the compound rest parallel to the ways of the lathe, and use a facing cutter bit to cut out the fillet left in the corner by the roughing bit. Using longitudinal feed, finish the small diameter up to the finished size of the shoulder. Lock the carriage and use the compound rest to feed the bit the additional amount necessary to finish the workpiece to the proper length. Engage the crossfeed to carry the bit away from the small diameter and face the shoulder.

26. PARTING.

a. General. Parting is the procedure of cutting a piece of stock in two on the lathe. A parting cutter bit (fig 8) is used for this operation and must be carefully ground to provide side clearances on both sides to prevent binding. Cutting oils should be used for most parting operations since the bit is subjected to greater heat due to the large cutting surface.

b. Mounting workpieces for parting. It is best to mount a workpiece to be parted in a chuck although parting can be accomplished between centers if the piece cannot be successfully chuck-mounted. Steady rests or follower rests should be set up on each side of the parting cutter bit if the piece is between centers. For successful parting, the lathe spindle bearings must fit snugly and the cross slide and compound rest gibs should be taken up fairly tight to avoid lost motion.

c. Position of parting cutter bit. The parting cutter bit should be positioned perpendicular to the axis of the workpiece with its cutting edge centered on the horizontal center line of the piece as in facing (fig 41).

d. Parting operation. The cutting speed for parting should be comparable to turning speeds, and the feed should be sufficient to keep a thin chip coming from the workpiece continuously. A power feed of approximately 0.002 inch per revolution may be used although it is sometimes advisable to feed by hand, thereby retaining control of the cutter bit in case of emergency. If too much pressure is applied on the crossfeed, the bit will gouge; if insufficient pressure is applied, the bit will chatter. When parting a workpiece mounted between centers, do not cut through completely with the parting cutter bit, but leave a small amount of stock and finish cutting with a hacksaw or chisel. If the workpiece is supported between centers and the bit is permitted to cut too far, the piece will bend and squeeze the bit, probably breaking the bit and damaging the piece. Except for the parting of cast iron and brass, a suitable cutting oil should be used.

27. TAPER TURNING.

a. General. Taper turning is the process of machining a workpiece to a diameter which increases uniformly, thus forming a section of a cone. Tapers can be either external or internal; if a bar has a tapered outside diameter, it has an external taper; if the walls of a hole are tapered, the piece has an internal taper. External tapers can be turned on a lathe by setting over the tailstock spindle, by setting an angle on the compound rest, or by using a taper attachment if the lathe is so equipped. The method used depends on the length of taper, the angle of tapers, and the number of pieces to be machined.

b. Characteristics of tapers.

(1) The usual method of expressing the taper of a workpiece is in changes of the diameter in inches of diameter per foot of length. For example, if a piece of metal 1 foot long is 3 inches in diameter at one end and 1 inch in diameter at the other end, the taper is said to be 2 inches per foot.

(2) To determine the t.p.f. (taper in inches per foot) of a workpiece, use the following formula:

$$\text{t.p.f.} = \frac{D_1 - D_2}{L}$$

where, t.p.f. = taper (in in. per ft);

D_1 = diameter (in in.) of workpiece at large end;
D_2 = diameter (in in.) of workpiece at small end;
L = length of taper (in ft.) measured along centerline of workpiece.

For example a workpiece 3 feet long which is 4 inches in diameter at one end and 2 inches in diameter at the other end has a taper calculated as follows:

$$\text{t.p.f.} = \frac{D_1 - D_2}{L} = \frac{4 - 2}{3} = 2/3 \text{ inch per foot.}$$

(3) Another means of expressing the taper is to specify the included angle between the sides of the workpiece (not the angle between a side and the centerline). The formula for calculating one-half of the angle is as follows:

$$\text{tangent } \alpha = \frac{\text{t.p.f.}}{24}$$

where, α = one-half of included angle between sides;
t.p.f. = taper (in inches per foot).

For example, a workpiece with a taper of 2/3 inch per foot has an included angle calculated as follows:

$$\text{tangent } \alpha = \frac{\text{t.p.f.}}{24} = \frac{2/3}{24} = \frac{2}{72} = 0.02778$$

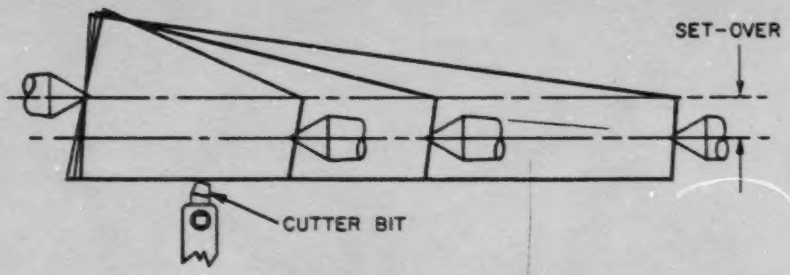
The angle α whose tangent is 0.02778 equals $1^\circ 35'$, nearly; then, since angle α is one half of the included angle, the included angle is equal to twice angle α or 3° and $10'$.

(4) Taper turning operations will often be the reproduction of widely used tapers such as the Morse standard tapers which are used for lathe and drill press spindles by most manufacturers, the Brown and Sharpe tapers which are commonly used for milling machine spindles and milling cutter shanks, and several other standard tapers. The Morse taper is approximately 5/8 inch per foot and the Brown and Sharpe taper is 1/2 inch per foot. Taper pins used in some assembly work have a taper of 1/4 inch per foot.

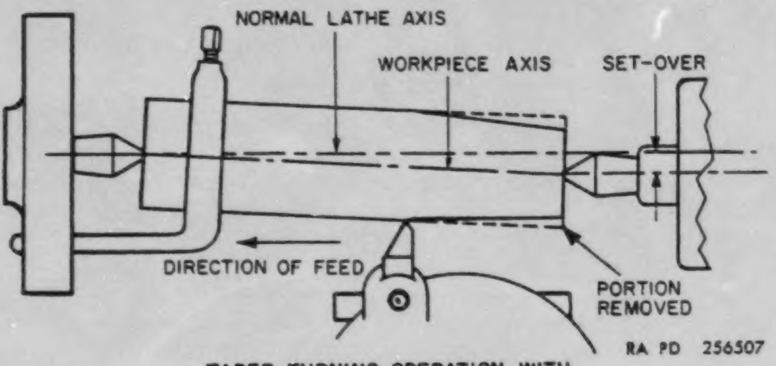
c. Taper turning with the tailstock setover.

(1) Setting the tailstock out of alinement is a common method for turning a taper. This method is applicable only to comparatively slight tapers because the lathe centers do not have full bearing on the workpiece. Center holes are likely to wear out of their true positions if the bearing of the lathe centers is set over too far, causing poor results and damaging the lathe centers.

(2) The most difficult operation in taper turning by offsetting the tailstock is determining the proper distance the tailstock should be moved over to achieve the desired taper. Two factors affect the amount of tailstock setover; the taper per foot desired and the length of the workpiece. If the setover remains constant, pieces of different lengths will be machined with different tapers (fig 44).


SET-OVER
CUTTER BIT

EFFECT OF FIXED AMOUNT OF SET-OVER WITH DIFFERENT LENGTHS OF WORKPIECES


NORMAL LATHE AXIS
WORKPIECE AXIS
SET-OVER
DIRECTION OF FEED
PORTION REMOVED
RA PD 256507

TAPER TURNING OPERATION WITH TAILSTOCK SET OVER

Figure 44. Taper turning with tailstock setover.

(a) The formula for calculating the correct setover for a given taper is as follows:

$$\text{setover} = \frac{\text{t.p.f.}}{2} \times L$$

where, setover = setover (in in.);

t.p.f. = taper (in in. per ft.);

L = length of taper (in ft.) measured along center of workpiece.

For example, the amount of setover required to machine a bar 42 inches (3.5 ft.) long with a taper of 1/2 inch per foot is calculated as follows:

$$\text{setover} = \frac{\text{t.p.f.}}{2} \times L = \frac{1/2}{2} \times 3.5 = \frac{3.5}{4} = 0.875 \text{ inch.}$$

Therefore, the tailstock should be set forward 0.875 inch.

(b) The formula for calculating the correct setover when diameters for each end of the workpiece are given instead of the taper is as follows:

$$\text{setover} = \frac{D_1 - D_2}{2} \times \frac{L_2}{L_1}$$

OS 424, 8-P55

where, setover = setover (in in.);
D_1 = diameter (in in.) of workpiece at large end;
D_2 = diameter (in in.) of workpiece at small end;
L_2 = total length (in ft.) of workpiece;
L_1 = length of taper (in ft.) measured along centerline of workpiece.

For example, the amount of setover required to machine a bar 36 inches (3 feet) in length for a distance of 18 inches (1.5 feet) when the diameter at one end is 1-1/2 (1.500) inches and 1-3/4 (1.750) inches at the other is calculated as follows:

$$\text{setover} = \frac{D_1 - D_2}{2} \times \frac{L_2}{L_1} = \frac{1.750 - 1.500}{2} \times \frac{3}{1.5} = \frac{0.250}{2} \times \frac{3}{1.5} =$$

0.250 inch.

Therefore, the tailstock should be set forward 0.250 inch.

(3) Another important consideration in calculating the setover is the distance that the lathe centers enter the workpiece. The length of the workpiece (L_2 in formula in c(2)(b) above) should be considered as the distance between the points of the centers for the above computations. Therefore, if the centers enter the workpiece 1/8 inch on each end and the length of the workpiece is 18 inches, subtract 1/4 inch from 18 inches, and compute the setover of the tailstock using 17-3/4 inches as the length (L_2).

(4) To set the tailstock over, loosen the forward adjusting screw on the tailstock cricket and tighten the rear adjusting screw. Move the tailstock center to the headstock center (fig 33) so that the distance of offset can be measured by a rule placed between the centers. Normally, the tailstock is set forward (fig 44) of its alinement position which results in a taper with the small diameter at the tailstock end of the workpiece. If the small diameter is desired at the headstock end of the workpiece, set the tailstock rearward of its alinement position.

(5) To cut the taper, start the rough turning at the end which will be the small diameter and feed longitudinally toward the large end (fig 44). If the tailstock is set over to the front, the feed will be from right to left; and the cutter bit, a right-hand turning cutter bit or a roundnose turning cutter bit, should have its cutting edge exactly at the horizontal centerline of the workpiece, not above center as with straight turning.

d. Taper turning with compound rest.

(1) One of the three commonly used methods for turning tapers on a lathe is by use of the compound rest. This method is especially suitable for turning or boring short, steep tapers, or bevels and is generally unsuitable for turning tapers greater than 2 to 3 inches in length because of the limited movement of the compound rest slide on most lathes.

(2) To machine a taper by this method, the compound rest is swiveled and locked at an angle which is one-half the included angle (b(3) above) of the taper, or the angle (angle α in formula in b(3) above) formed between one side of the taper and the axis. The cutter bit is then fed by turning the compound rest feed handle to move the tool along the axis of the compound rest.

(3) The angle of the taper must be known to set the compound rest. If the taper is given in taper inches per foot, the angle will have to be computed (b(3) above). This angle will then have to be divided by two because only one-half of the angle must be set on the compound rest.

(4) The cutter bit should be set exactly on center for height. Turn the compound rest handle to move the compound rest near its right rear limit of travel to assure sufficient traverse of the compound rest slide to complete the taper. Bring the bit up to the workpiece by traversing and crossfeeding the carriage. Lock the carriage to the lathe bed when the bit is in position. Cut from right to left, adjusting the depth of feed for each cut by moving the crossfeed handle. Feed the bit by hand, using the compound rest feed handle. Roughing and finishing cuts should be consistent with the practice prescribed for straight turning.

e. Taper turning with a taper attachment.

(1) The third method in general use for tapers turning in the lathe is by means of a taper attachment (fig 45). Some engine lathes are equipped with a taper attachment as standard equipment, and most lathe manufacturers have a taper attachment available. Taper turning with a taper attachment, although generally limited to a taper of 3 inches per foot and to a set length of 12 to 24 inches, affords the most accurate means for turning or boring tapers. The taper can be set directly on the taper attachment in inches per foot and on some attachments the taper can be set in degrees as well.

(2) A typical taper attachment for the lathe is illustrated in figure 45. Before using the taper attachment, the crossfeed screw must be disconnected by removing the crossfeed screw bolt. A bed bracket attaches to the lathe bed and keeps the angle plate from moving to the left or right. The carriage bracket moves along the underside of the angle plate in a dovetail and keeps the angle plate from moving in or out on the bed bracket. The taper to be cut is set by placing the guide bar, which clamps to the angle plate, at an angle to the ways of the lathe bed. Graduations on one or both ends of the guide bar permit this adjustment without measurement being necessary. A sliding block which rides on a dovetail on the upper surface of the guide bar is secured, during operation, to the cross slide bar of the carriage, the crossfeed screw of the carriage being disconnected. Therefore, as the carriage is traversed during the feeding

operation, the cross slide bar follows the guide bar, moving at the predetermined angle from the ways of the bed to cut the taper. It is not necessary to remove the taper attachment when straight turning is desired; the guide bar can be set parallel to the ways, or the clamp handle can be released permitting the sliding block to move without affecting the cross slide bar, and the crossfeed screw can be reengaged to permit power crossfeed and control of the cross slide from the apron of the carriage.

(3) The taper attachment gives very accurate results when the workpiece is mounted between centers because the lathe centers have full bearing on the piece throughout the operation.

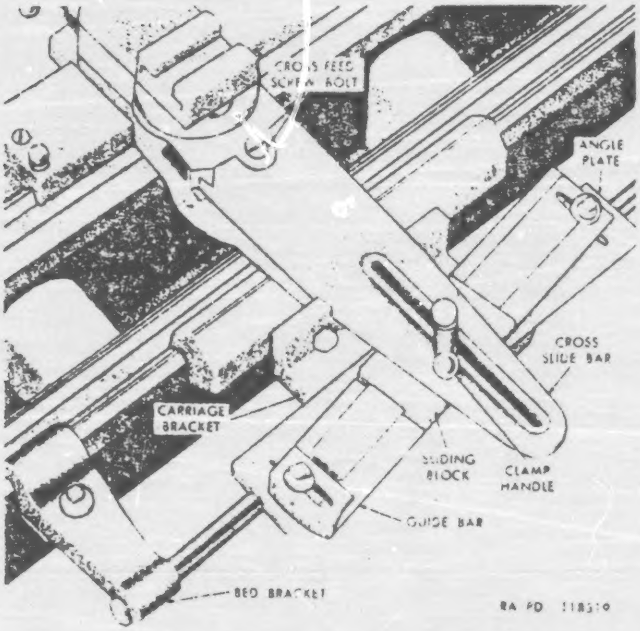


Figure 45. Typical lathe taper attachment.

(4) A telescopic taper attachment which is similar to the plain attachment ((2) above), except that it is equipped with a telescopic crossfeed screw that eliminates the necessity of disconnecting the crossfeed screw, is sometimes used. To use the telescopic attachment, first set the cutting bit for the required diameter of the work and engage the attachment by tightening the binding screws. To change back to plain turning, it is necessary only to loosen the binding screws.

(5) When cutting a taper using the taper attachment, the feed of the cut should be from the intended small diameter toward the intended large diameter. Cutting in this manner, the depth of cut is greater at the start of each cut and therefore can be better controlled to prevent damage to the cutter bit, workpiece, and lathe by forcing too deep a cut.

f. Checking tapers for accuracy.

(1) While the taper is being turned, it is good practice to stop the lathe after complete traverses of the cutter bit and measure the diameters at each end to determine that the taper is being cut to the required dimensions. An error in calculation must be discovered early because it may be too late for correction when the workpiece is completely rough turned. Also, lay a straightedge along one side of the taper to assure that the taper is uniform. Lack of uniformity can be caused by the presence of backlash in a taper attachment on byplay in the compound rest if the compound rest method is being used.

(2) After the taper is completed, it should be tested in a taper plug gage or taper socket gage. If no gage is available, the taper should be tested in the hole it is to fit. To test the taper with a gage, mark the piece to be tested with chalk or Prussian blue pigment, insert it snugly into the gage, and turn it through one whole revolution. If the marks on the workpiece have been rubbed evenly, the taper is correct; if they have been rubbed off at only one end, the fit is inaccurate and the taper has been cut incorrectly. To test an internal taper, the procedure is identical except the gage should be marked instead of the workpiece.

28. SCREW THREAD CUTTING.

a. General. A screw thread is a helical projection of uniform section on the internal or external surface of a cylinder or cone. Threads may be formed on the lathe by use of taps and dies or by cutting them with the thread cutting mechanisms of the lathe. Cutting screw threads is among the most common of lathe operations. Before attempting such operations, however, the operator should have some familiarity with the fundamental principles of threads and the types generally in use.

b. Screw thread terminology (fig 46). The common terms and definitions below are used in calculating screw threads and will be used in discussing threads and thread cutting.

(1) External or male thread. A thread on the outside of a cylinder or cone.

(2) Internal or female thread. A thread on the inside of a hollow cylinder or bore.

(3) Pitch. The distance from a given point on one thread to a similar point on a thread next to it, measured parallel to the axis of the cylinder. The pitch in inches is equal to one divided by the number of threads per inch.

(4) Lead. The distance a screw thread advances axially in one complete revolution. On a single-thread screw, the lead is equal to the pitch ((3) above). On a double-thread screw the lead is equal to twice the pitch, and on a triple-thread screw, the lead is equal to three times the pitch.

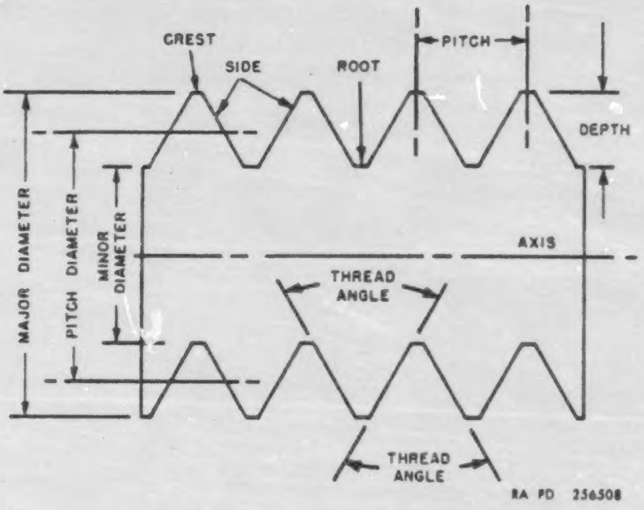


Figure 46. Terms applied to screw threads.

(5) Crest (also called "flat"). The top or outer surface of the thread joining the two sides.

(6) Root. The bottom or inner surface joining the sides of two adjacent threads.

(7) Side. The side of a thread is the surface which connects the crest and the root.

(8) Thread angle. The angle included between the sides of adjacent threads, measured in an axial plane. For most V-threads, the angle is fixed at 60°

(9) Depth. The depth of a thread is the distance between the crest and root of a thread, measured perpendicular to the axis.

(10) Major diameter. The major diameter is the largest diameter of a screw thread.

(11) Minor diameter. The minor diameter is the smallest diameter of a screw thread.

(12) Pitch diameter. The pitch diameter is the diameter of an imaginary cylinder, the surface of which would pass through the threads at such points to equalize the widths of the threads and spaces cut by the surface of the cylinder.

c. Screw thread forms. The most commonly used screw thread forms are discussed below. Of these threads, the unified screw thread and the American (National) Standard thread are the most widely required for locking devices. The Acme, square, and 29° worm threads are most common for devices which function to transmit motion.

(1) Unified screw thread (fig 47). The unified screw thread is the newest of standard thread forms, being acceptable for interchangeable parts by the United States, Great Britain, and Canada. The unified thread is a variation of the American (National) Standard thread form, having an included thread angle of 60°. On external threads of the unified form, the root is rounded and the crest is optionally rounded or left flat; in the United States, the flat crest is preferred. The internal thread of the unified form is like the American (National) thread form but is not cut as deep, leaving a crest of one-fourth the pitch instead of one-eighth the pitch. The pitches, basic dimensions, and tolerances for sizes 1/4 inch and larger are basically the same for the unified and American (National) thread forms. The coarse thread series of the unified system is designated UNC and the fine thread series UNF.

(2) American (National) Standard thread (fig 47).

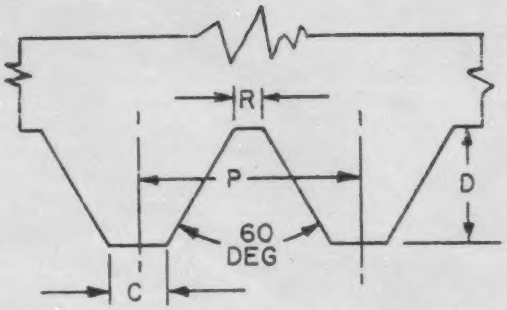
(a) The American (National) Standard thread form is the most commonly used thread form in the United States. It is a modification of the 60° sharp V-thread, having its crest and root flattened, the flats produced being equal to one-eighth the pitch of the screw. This form has a locking capacity similar to the old sharp V-thread but will stand greater abuse without damage, having no sharp angles.

(b) The American National Standard thread form is used in five series of pitches as follows:

National Fine (NF) (formerly the SAE Standard screw thread).
National 8-Pitch.
National 12-Pitch.
National 16-Pitch.
National Coarse (NC) (formerly the USS screw thread).

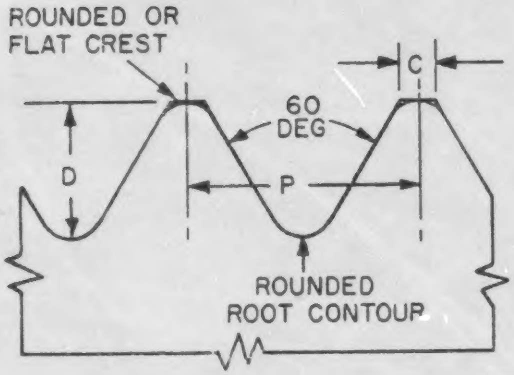
In the coarse and fine series, the number of threads per inch decreases as the diameters increase. These series are intended for general use. Eight-pitch is used for bolts, cylinder head studs, high-pressure pipe flanges, and so on. Twelve-pitch is used in modern machine and boiler construction for thin nuts, shafts, and sleeves. Sixteen-pitch is intended for adjusting collars, bearing retaining nuts, or any part requiring a fine thread.

(3) SAE extra fine threads. The SAE Extra Fine Thread Series has many more threads per inch for given diameters than any series of the American (National) Standard ((2) above). The form of thread is the same as the American (National) Standard. These small threads are used in thin metal where the length of thread engagement is small, in cases where close adjustment is required, and where vibration is great. It is designated EF (Extra Fine).



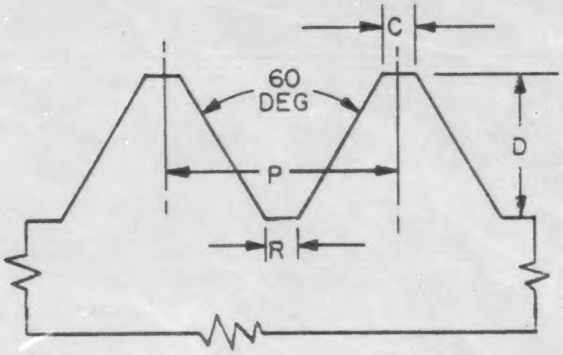
D=DEPTH=0.54127 X PITCH
C=CREST=PITCH ÷ 4

UNIFIED SCREW THREAD
(INTERNAL THREAD)


ROUNDED OR
FLAT CREST
C
60
DEG
D
P
ROUNDED
ROOT CONTOUR

D=DEPTH=0.61344 X PITCH
C=CREST=PITCH ÷ 8

UNIFIED SCREW THREAD
(EXTERNAL THREAD)



D=DEPTH=0.64952 X PITCH
C=CREST=PITCH ÷ 8

AMERICAN NATIONAL STANDARD THREAD

FOR ABOVE THREAD FORMS, P=PITCH=1 ÷ THREADS PER INCH, AND
R=ROOT=PITCH ÷ 8

RA PD 256509

Figure 47. General form dimensions for unified and American (National) Standard screw threads.

OS 424, 8-P62

(4) Acme screw thread (fig 48). The Acme screw thread form is classified as a power-transmitting type of thread. This is because the 29° included thread angle at which its sides are established reduces the amount of friction when matching parts are under load. Because the root and crest are wide, this thread form is strong and capable of carrying a heavy load. The Acme thread form is especially suitable for lathe lead screws and similar power transmitting uses.

(5) Twenty-nine-degree worm screw thread (fig 48). The 29° worm screw thread and the Acme thread are similar in that they both have an included thread angle of 29°. However, these thread forms should not be confused since they are different in depth of thread and width of crest and root.

(6) Square screw thread (fig 48). Because of their design and strength, square screw threads are used for vise screws, jack screws, and other devices where maximum transmission of power is needed. All surfaces of the square thread are square with each other and the sides are perpendicular to the center axis of the threaded part. Because the contact areas are relatively small and do not wedge, friction between matching threads is reduced to a minimum under heavy pressure.

d. Thread fit and designations.

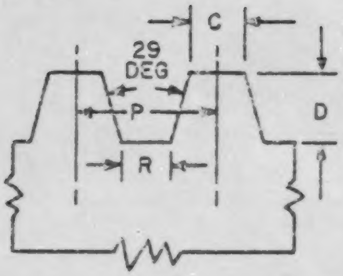
(1) Thread fit.

(a) The Unified and American (National) Standard thread forms designate classifications for fit to insure that mated threaded parts fit to the tolerances specified.

(b) The Unified screw thread form specifies several classes of threads which are classes 1A, 2A, and 3A for screws or external threaded parts, and 1B, 2B, and 3B for nuts or internal threaded parts. Classes 1A and 1B are for a loose fit where quick assembly and rapid production are important and shake or play is not objectionable. Classes 2A and 2B provide a small amount of play to prevent galling and seizure in assembly and use, and sufficient clearance for some plating; classes 2A and 2B are recommended for standard practice in making commercial screws, bolts, and nuts. Classes 3A and 3B have no allowance and 75 percent of the tolerance of classes 2A and 2B. A screw and nut in this class may vary from a fit having no play to one with a small amount of play. Only high grade products are held to class 3 specifications.

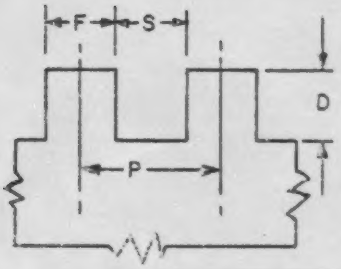
(c) Four distinct classes of screw thread fits between mating threads (as between bolt and nut) have been designated for the American (National) Standard screw thread form. Fit is defined as "the relation between two mating parts with reference to ease of assembly." These four fits are produced by the application of tolerances which are listed in the standards. The four fits are described as follows:

1. Class 1 fit. This fit is recommended only for screw thread work where clearance between mating parts is essential for rapid assembly and where shake or play is not objectionable.



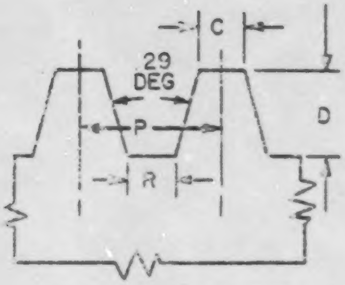
D=DEPTH=1/2 PITCH + 0.01 INCH
C=CREST=0.03707 X PITCH
R=ROOT=CREST-0.0052 INCH

ACME SCREW THREAD



D=DEPTH=1/2 PITCH
F=FLAT=1/2 PITCH
S=SPACE=
FOR SCREW: 1/2 PITCH
FOR NUT: 1/2 PITCH + 0.001
TO 0.002 INCH
CLEARANCE

SQUARE SCREW THREAD



D=DEPTH=0.6866 X PITCH
C=CREST=0.335 X PITCH
R=ROOT=0.310 X PITCH

29-DEG WORM SCREW THREAD (BROWN AND SHARPE)

FOR ABOVE THREAD FORMS, P=PITCH=1÷THREADS PER INCH

RA PD 256510

Figure 48. General form dimensions for Acme, square, and 29° worm screw thread forms.

2. Class 2 fit. This fit represents a high quality of commercial thread product and is recommended for the great bulk of interchangeable screw thread work.

3. Class 3 fit. This fit represents an exceptionally high quality of commercially threaded product and is recommended only in cases where the high cost of precision tools and continual checking are warranted.

4. Class 4 fit. This fit is intended to meet very unusual requirements more exacting than those for which class 3 is intended. It is a selective fit if initial assembly by hand is required. It is not, as yet, adaptable to quantity production.

(2) Thread designations. In general, screw thread designations give the screw number (or diameter) first, then the initial letters of the series, NC (National Coarse), UNF (Unified Fine), NS (National Special), etc., followed by the class of fit. If a thread is left hand, the letters L. H. follow the fit. Examples of designations are as follows:

(a) No. 10 (0.190)-24NC-3—This is a number 10 (0.190-in. dia) thread, 24 National Coarse threads per inch, and a class 3 fit.

(b) 1/4-28UNF-2A L. H.—This is a 1/4-inch diameter thread, 28 Unified Fine threads per inch, left-hand thread, and a class 2A fit.

(c) 0.205-26NS-2—This is a 0.205-inch diameter, 26 National Special threads per inch, and a class 2 fit.

e. Thread cutter bits and cutters.

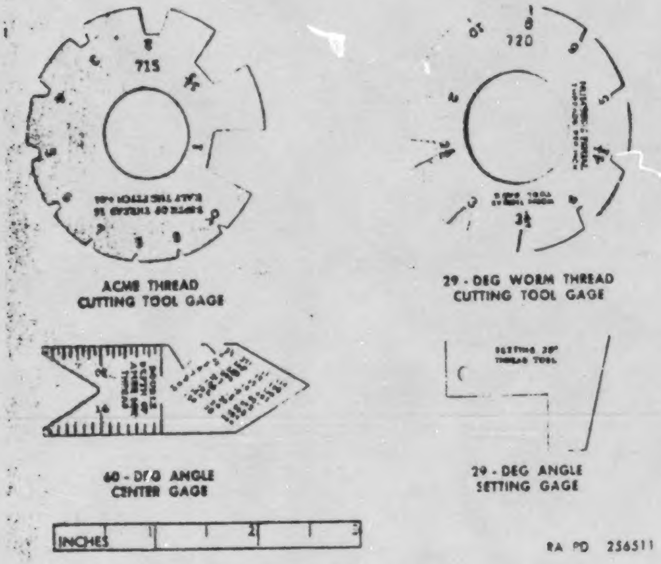
(1) It should be noted that these tools as mentioned are intended for cutting sharp V-threads with a 60° thread angle. For cutting threads to the Unified or American (National) Standard forms, it is necessary to grind the point of the cutter bit to the shape of the thread root. In the case of the American (National) Standard thread, a flat should be carefully ground at the point of the bit, perpendicular to the center line of the 60° thread angle. For the Unified thread, the end of the bit should be ground with the required radius for external threads or the required flat for internal threads. In both cases, the tool should be ground to the angle specified by the pitch of the thread.

(2) For Acme and 29° wormscrew threads, the cutter bit must be ground to form a point angle of 29°. Side clearances must be sufficient to prevent rubbing on threads of steep pitch. The end of the bit is then ground to a flat which agrees with the width of the root for the specific pitch being cut. Thread cutting tool gages (fig 49)| are available to simplify the procedure and make computations unnecessary.

(3) To cut square threads, a special thread cutter bit is required.

(a) Before the square thread cutter bit can be ground it is necessary to compute the helix angle of the thread to be cut (fig 50). Compute the helix angle by drawing a line equal in length to the thread circumference at its minor diameter (this is accomplished by multiplying the minor diameter by 3.1416 (pi)). Next draw a line perpendicular to and at one end of the first line, equal in length to the lead of the thread. If the screw is to have a single thread, the lead will be equal to the pitch (b(3) above). Connect the ends of the angle so formed to obtain the helix angle.

(b) The tool bit should be ground to the helix angle (fig 50) and the clearance angles for the sides should be within the helix angle. Note that the sides are also ground in toward the shank to provide additional clearance.



ACME THREAD CUTTING TOOL GAGE

29-DEG WORM THREAD CUTTING TOOL GAGE

60-DEG ANGLE CENTER GAGE

29-DEG ANGLE SETTING GAGE

RA PD 256511

Figure 49. Thread cutting tool gages.

(c) The end of the tool (fig 50) should be ground flat, the flat being equal to one-half the pitch of the thread to produce equal flats and spaces on the threaded part.

f. Position of thread cutter bit for use.

(1) The thread cutter bit must be placed exactly on line horizontally with the axis of the workpiece. This is especially important for thread cutter bits since a slight variation in the vertical position of the bit will change the thread angle being cut.

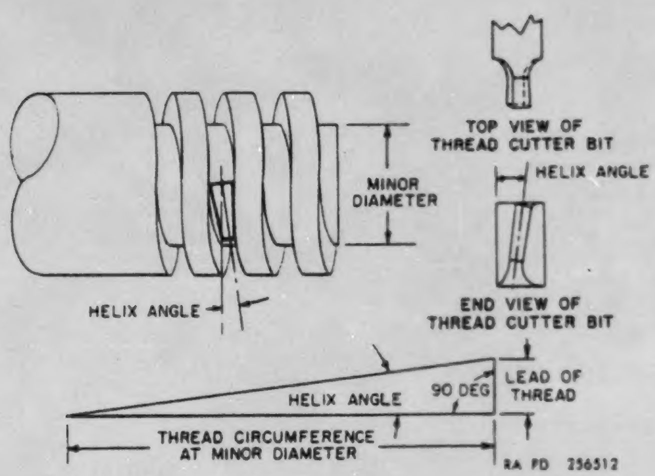

TOP VIEW OF
THREAD CUTTER BIT
HELIX ANGLE
MINOR
DIAMETER
END VIEW OF
THREAD CUTTER BIT
HELIX ANGLE
LEAD OF
THREAD
HELIX ANGLE
90 DEG
THREAD CIRCUMFERENCE
AT MINOR DIAMETER
RA PD 256512

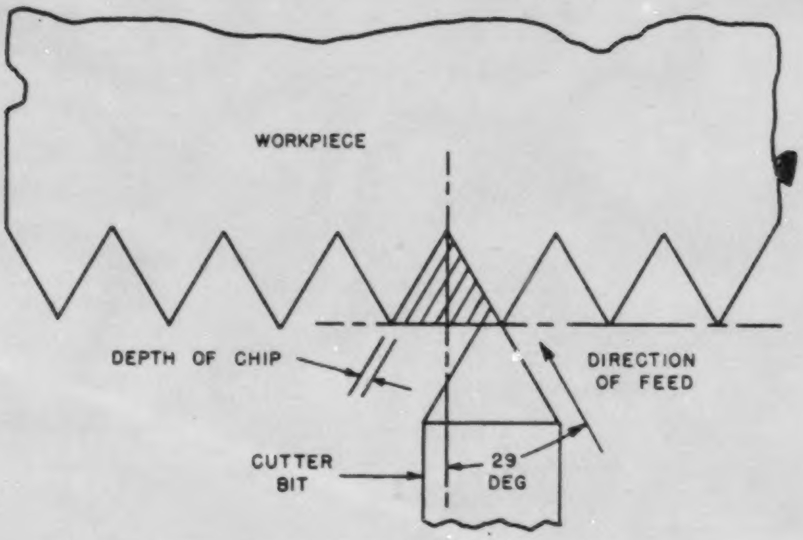
Figure 50. Thread cutter bit for square threads.

(2) The thread cutter bit must be positioned so that the centerline of the thread angle ground on the bit is exactly perpendicular to the axis of the workpiece. The easiest way to make this alinement is by use of a center gage (fig 49). The center gage will permit checking the point angle at the same time as the alinement being effected. The center gage is placed against the workpiece, and the cutter bit is adjusted on the toolpost so that its point fits snugly in the 60° angle notch of the center gage (fig 51).

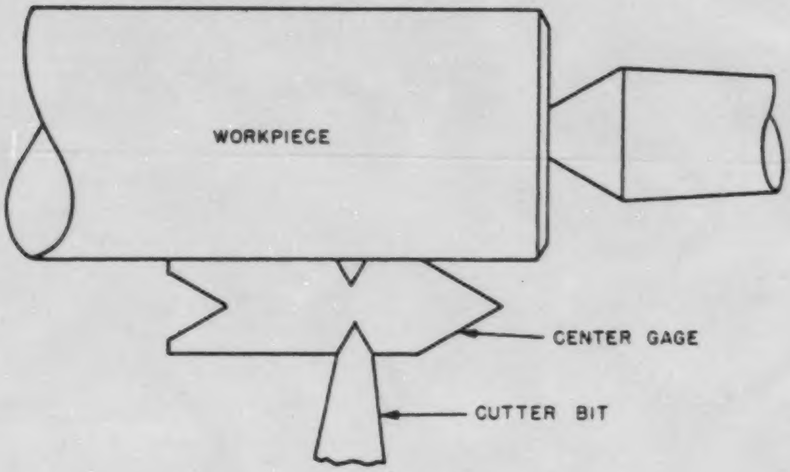
g. Setting lathe thread cutting mechanism for proper feed.

(1) General. In cutting threads on a lathe, the pitch of the thread or number of threads per inch obtained is determined by the speed ratio of the headstock spindle and the lead screw which drives the carriage. Lathes equipped for thread cutting have gear arrangements for varying the speed of the lead screw. Most modern lathes have a quick-change gear box for varying the lead screw to spindle ratio, but many older lathes, modern inexpensive lathes, and special types of lathes come equipped with standard change gears which must be arranged by computation to achieve the desired speed ratio.

(2) Quick-change gear box. For lathes equipped with quick-change gear boxes, the operator need only follow the instructions on the direction plates of the lathe to set the proper feed to produce the desired number of threads per inch. Once set to a specific number of threads per inch, the spindle speed can be varied depending upon the material being cut and the size of the workpiece, without affecting the threads per inch.


WORKPIECE
DEPTH OF CHIP
DIRECTION OF FEED
CUTTER BIT
29 DEG

THREAD CUTTING WITH COMPOUND REST SET AT 29-DEGREE ANGLE


WORKPIECE
CENTER GAGE
CUTTER BIT

USING CENTER GAGE TO SET CUTTER BIT RA PD 256513

Figure 51. Setting up cutter bit for thread cutting operation.

(3) Standard-change gears. Lathes equipped with standard-change gears require that the operator be familiar with the methods of selecting the proper gears to produce the desired thread pitch in case the manufacturer-supplied gear tables are missing. On most lathes with standard-change gears, the gears may be arranged in a simple gear train or in a compound gear train.

(a) Simple gear train (fig 52).

1. The basic gears which control the ratio between spindle speed and lead screw speed are the stud gear and the lead screw gear. The stud gear mounts to a shaft which revolves at the same speed as the spindle and therefore can be considered in this discussion as representing spindle speed in revolutions per minute. The lead screw gear is usually connected directly to the lead screw and therefore moves at the same speed as the lead screw. In a simple gear train, the stud gear and the lead screw are meshed together or coupled by an idler gear. If the idler gear is used, it can be of any size or number of teeth convenient for coupling since it only transmits motion from one gear to the other and does not affect the ratio of the stud or lead screw gears.

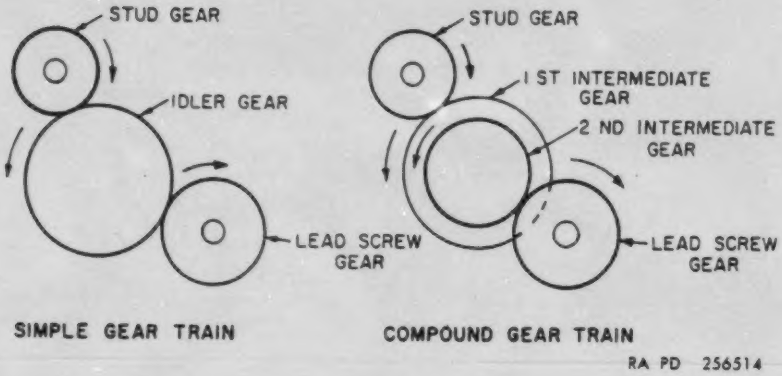


Figure 52. Simple and compound gear trains.

2. The threads per inch of the lead screw must be known to compute the gearing for a specific ratio. The rule for determining the number of teeth of the stud gear and lead screw gear for a simple gear train is as follows: Multiply the number of threads per inch of the lead screw and the number of threads to be cut by a common number. The products will be the number of teeth that the stud gear and the lead screw gear should have respectively. For example, suppose that a machinist wants to cut a screw with 10 threads per inch on a lathe having a lead screw with 4 threads per inch. The procedure would be to multiply 10 and 4 by any convenient

number, say 6. Then, 6 x 4 = 24 and 6 x 10 = 60. The stud gear should have 24 teeth and the lead screw gear should have 60 teeth to produce the desired ratio to cut 10 threads per inch. If gears of 24 and 60 teeth are not available, multiply 10 and 4 by another number until the products coincide with the number of teeth on available gears.

3. Whenever the thread to be cut is finer than the thread of the lead screw, the gear with the fewest teeth will be the stud gear. If the thread to be cut is coarser than the lead screw, the gear with the fewest teeth will be the lead screw gear.

(b) Compound gear train (fig 52).

1. If the proper ratio between spindle and lead screw cannot be obtained by simple gearing, a compound gear train must be used. For example, if it is desired to cut 80 threads per inch with a lead screw having 8 threads per inch, and the smallest change gear available has 24 teeth, the lead screw gear must have 240 teeth which would be too large in diameter to fit the lathe. By compounding the gears, it would be possible to cut 80 threads per inch with the gears generally available.

2. In the compound gear train, two intermediate gears replace the idler gear of the simple gear train. The intermediate gears are mounted to the same shaft and are keyed together. The gear driven by the stud gear is known as the first intermediate gear and the gear that drives the lead screw gear is known as the second intermediate gear. An idler gear can be used if necessary in this gear train, but will reverse the direction of the lead screw gear, and make reversal of the stud gear-to-spindle connection necessary.

3. To compute compound gear arrangements, the following rule should be applied: Establish the ratio between the number of threads per inch to be cut and the number of threads per inch of the lead screw. Factor each term of the ratio, that is, determine two numbers for each term which, when multiplied by each other, result in the number of the ratio term. The resulting four numbers when each are multiplied by a convenient number will be the number of teeth in the four gears, the stud gear and second intermediate gear representing the smaller term, and the first intermediate gear and lead screw gear representing the larger term of the ratio. For example, to cut 80 threads per inch with a lathe having a lead screw of 8 threads per inch, the ratio would be 8 to 80 (8 units to 80 units). Factoring

each term, 8 = 2 x 4 (factors), and 80 = 8 x 10 (factors). Then multiplying 2, 4, 8, and 10 each by a convenient number, say 12, the result is the ratio, 24 x 48:96 x 120. The gearing then must be:

Stud gear - 24 teeth.
First intermediate gear - 96 teeth.
Second intermediate gear - 48 teeth.
Lead screw gear - 120 teeth.

(4) Engaging the feed. The carriage is connected to the lead screw of the lathe for threading operations by engaging the half nut on the carriage apron with the lead screw. A control is available to reverse the direction of the lead screw, and it should be determined that the screw turns in the desired direction, for left- or right-hand threading as desired. Feed the cutter bit from right to left to produce a right-hand thread. Feed the cutter bit from left to right to produce a left-hand thread.

h. Direction of feed.

(1) For standard 60° threads of the sharp V-type, the American (National) Standard form, and the Unified form the cutter bit should be moved in at an angle of 29° (fig 51) so that the left side of the bit does most of the cutting and a free curling chip may result. The direction is controlled by setting the compound rest at the 29° angle before adjusting the cutter bit perpendicular to the workpiece axis. The depth of cut is then controlled by the compound rest feed handle.

(2) For Acme, 29° worm, and square threads, the cutter bit is fed into the workpiece at an angle perpendicular to the workpiece axis.

i. Threading cutting operation.

(1) Before cutting threads, turn down the workpiece to the major diameter of the thread to be cut. The workpiece may be set up in a chuck or between centers. If a long thread is to be cut, it is advisable to use a center rest because thread cutting can place a great strain on the workpiece.

(2) The usual practice in cutting threads is to take a very light initial cut and then check to see that the lathe has been geared correctly for the right number of threads per inch. If it is correctly geared, continue taking cuts until the thread reaches the depth wanted; in the case of Unified and American (National) Standard threads, this is determined by measuring the crest of the thread and in the case of sharp V-threads, when the thread becomes pointed.

(3) After each pass of the cutter bit, the operator must move the bit out of engagement with the thread being cut, and traverse

the carriage and bit back to the beginning of the thread. At the end of each cut, the half nuts are usually disconnected and the carriage returned to position of the next cut by hand. Some device must be provided, therefore, to engage the half nuts for the following cut at a point on the lead screw which will cause the cutter bit to follow the previous cut. If such a device is not available, it is necessary to leave the half nuts engaged at the end of the cut and return the cutter bit by reversing the feed.

(4) The usual device for accomplishing correct alinement of the cutter bit after the half nuts have been disengaged is the thread chasing dial (fig 53). This device is supplied as standard or optional equipment on all screw cutting lathes. It consists of a worm wheel which meshes with the lead screw, a dial, and a short shaft connecting the worm wheel to the dial. It is usually mounted to the right side of the carriage apron. The dial is calibrated with four numbered lines and four unnumbered lines between them. To use the thread chasing dial, engage the half nuts when the dial is alined for the particular number of threads per inch being cut. If the number of threads per inch is an even number, the half nuts can be reengaged for following cuts when any line on the dial is opposite the index. When cutting odd numbered threads, the half nuts can be reengaged where any numbered line is opposite the index. To cut all threads having a half a thread per inch (such as 11-1/2 threads per in.), the half nuts can be reengaged when any odd numbered line is opposite the index.

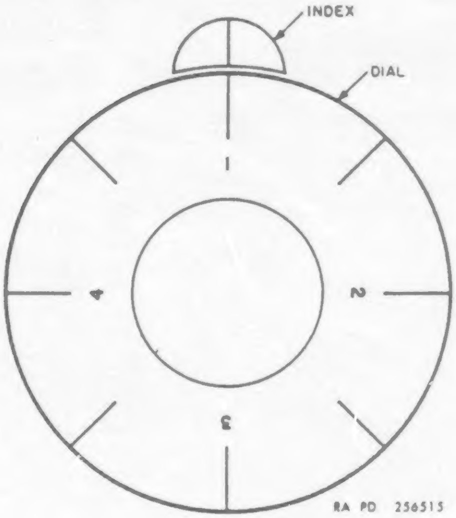


Figure 53. Thread chasing dial.

(5) Some lathes are equipped with a thread chasing stop bolted to the carriage which can be set to regulate the depth of cut for each traverse of the cutter bit or can be set to regulate the total depth of cut of the thread.

(6) When the thread is cut, the end must be finished in some way. The most common means of finishing the end is with a specially ground or 45° angle chamfer cutting bit (fig 54). To produce a rounded end, a cutter bit with the desired shape should be specially ground for that purpose.

j. Taper screw threads. Taper screw threads or pipe threads can be cut on the lathe by setting the tailstock over or by using a taper attachment. For the National Taper Pipe thread form, the taper is 3/4-inch per foot. Check the thread cutter bit carefully for clearances before cutting since the bit will not be entering the workpiece at right angles to the tapered workpiece surface.

Note. —In cutting a taper thread, the cutter bit should be set at right angles to the axis of the workpiece. Do not set the thread cutter bit at right angles to the taper of the thread.

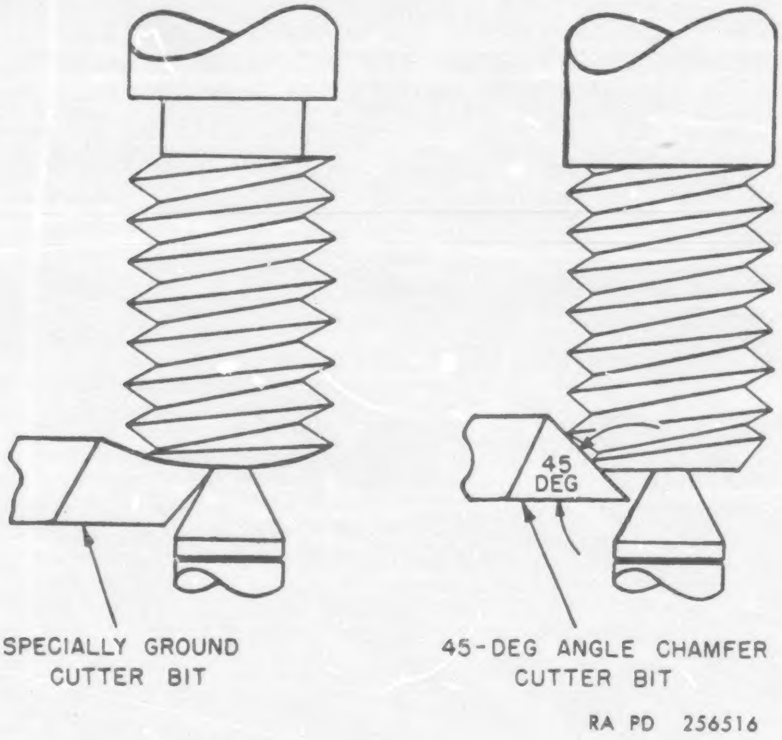


Figure 54. Two methods of finishing ends of threads.

OS 424, 8-P73

k. Thread measurement.

(1) The pitch of the threaded part must often be measured with close accuracy. A machinist's steel rule or a screw pitch gage is convenient for determining the pitch of any thread. When measuring with a machinist's steel rule (fig 55), do not count the thread at the end of the rule. Count the number of threads in 1 inch, or if a thread does not coincide with the inch mark, count the number of threads in 2 inches and divide by 2 to determine the threads per inch. When using the screw pitch gage (fig 55), select a gage that fits the threads to be measured exactly. The pitch or thread per inch can be read directly from the gage.

(2) The measurement of thread angles and pitch diameters is somewhat more involved but equally necessary if accurate fits are to be obtained. The simplest way to check the accuracy of a screw thread is to try it in the part which it is to fit. If this is impractical, a plug thread gage or a ring thread gage, if available, can be used to test the internally or externally threaded part. The ring or plug gage must be accurately machined and should be of the exact requirements of the part being tested in diameter, threads per inch, and class of fit.

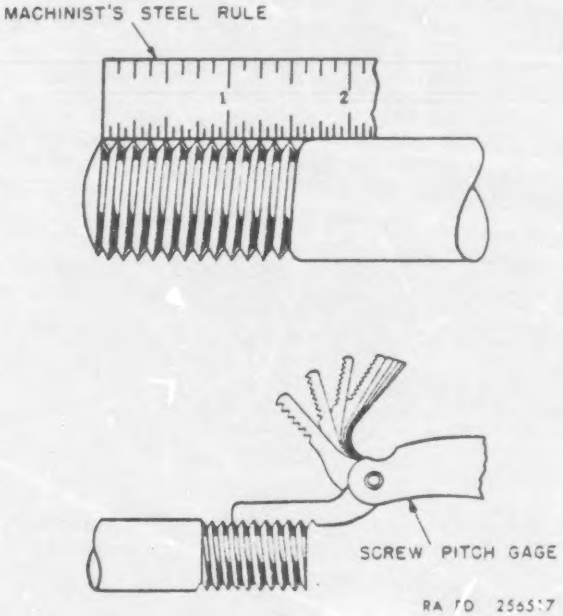


Figure 55. Two methods of measuring pitch of a screw.

(3) Accurate measurement of the pitch diameter of an externally threaded piece is achieved by measuring the thread with a thread micrometer caliper if available, or by the three-wire method (fig 56) which employs an outside micrometer caliper.

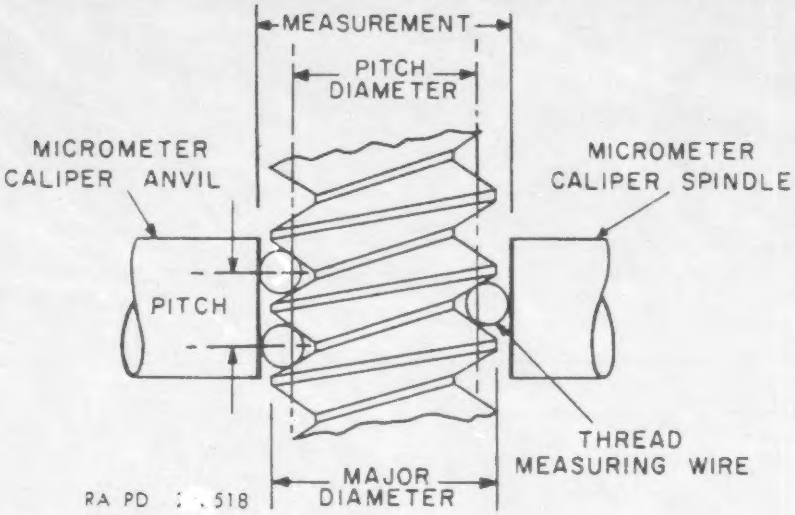


Figure 56. Measuring threads by the three-wire method.

(a) Measuring with thread micrometer caliper.

1. The thread micrometer caliper is made with the spindle pointed and the anvil notched so as to bear on the sidewalls of the thread. The point on the spindle is blunt to prevent interference with the root of the thread groove, and this bluntness limits the micrometer caliper to a specific range of thread sizes. Thread micrometer calipers are therefore manufactured in different size ranges, such as 1 inch: 8 to 13 threads, 14 to 20 threads, 22 to 30 threads; 2 inches: 14 to 20 threads, 22 to 30 threads, etc.

2. The thread micrometer caliper measures the pitch diameter of the thread by subtracting the single depth of the thread from its outside diameter. To use the thread micrometer caliper, first select the proper size micrometer caliper for the thread to be measured, look up in a table the correct pitch diameter for the screw, and lastly take a reading with the micrometer caliper.

(b) Measuring by the three-wire method (fig 56).

1. The three-wire method of measuring threads is considered the best method for extremely accurate measurement of pitch diameter. Three wires of the same diameter are placed into the thread groove and the outside micrometer caliper is used to measure over the wires. The pitch diameter is determined by subtracting the amount of wire projection above the pitch diameter from the micrometer caliper reading.

2. This method is dependent upon using the best wire size for measuring. The best wire is the size which touches the sides of the thread at the center of their slopes, in other words, at the pitch diameter. A formula by which the proper wire size may be determined if the pitch for a particular thread is not included is as follows:

$$D_w = \frac{0.57735}{N}$$

where, D_w = diameter of wire (in inches)
N = threads per inch.

For example, if 8 threads per inch have been cut, then,

$$D_w = \frac{0.57735}{N} = \frac{0.57735}{8} = 0.072 \text{ inch is correct diameter of wire to use.}$$

3. The wire to be used should be hardened and lapped steel wire, preferably within 0.0002 inch tolerance.

4. To find the correct micrometer caliper measurement for a screw size, use the following formula:

$$M = D_m + 3D_w - \frac{1.5155}{N}$$

where, M = Measurement across wires (in inches).
D_m = Major diameter (in inches) of screw.
N = Threads per inch.

For example, a 1/2-inch, 12-pitch thread (using a wire 0.04811 in. in diameter) has a measurement across wires calculated as follows:

$$M = D_m + 3D_w - \frac{1.5155}{N}$$

$$= 0.500 + 3(0.04811) - \frac{1.5155}{12} = 0.51803 \text{ inch.}$$

0.51803 inch is the correct micrometer caliper measurement for the screw size.

29. KNURLING.

a. General. Knurling is the process of grooving the surface of a workpiece by rolling depressions into it. This embossing procedure is done with a knurling tool pressed against the workpiece as it revolves. Knurling is used to provide a handgrip on the workpiece, for decorative appearance, and to enlarge diameters of work.

b. Setup for knurling. A workpiece can be knurled between centers or in a chuck. It is important that the piece be well supported since considerable pressure is required to emboss the pattern on some materials. The piece to be knurled is mounted between centers in the same manner as for straight turning.

c. Knurling tool. The knurling tool (fig 10) supports two knurls which revolve independently. The knurls may be of the diamond or the straight line pattern. The diamond pattern, which is more common, generally comes in three pitches: 14 (coarse), 21 (medium), and 33 (fine). These patterns are illustrated on figure 11.

d. Knurling operation.

(1) First it is necessary to locate the limits of the surface to be knurled, that is, the beginning and end of the knurled portion. Set the knurling tool so that the top knurl is the same distance above horizontal centerline of the workpiece as the lower knurl is below this centerline. The working faces of the knurls should be set parallel to the workpiece surface.

(2) Set the lathe to run at the lowest speed of the lathe back gear. Adjust the feed selector levers or change gears to provide a feed of approximately one-half the width of the knurl per revolution of the workpiece.

(3) Move the cross slide and carriage to position the knurling tool at the right end of the portion to be knurled. Start the lathe and force the knurls into the workpiece to a depth of about 1/64 inch by use of the hand crossfeed control.

(4) Check at this point to see that the knurling tool is mounted square to the workpiece. A perfect diamond pattern should be produced. If the knurls do not track properly and the diamond marking is split by one of the knurls, it is an indication that the knurling tool is not square or is mounted above or below center. When the tool makes the proper knurl, go over the entire surface. The workpiece and knurls should be well lubricated with cutting oil during the knurling operation.

30. BORING.

a. General.

(1) Boring is the enlarging and truing of a hole by removal of material from internal surfaces with a single-point cutter bit. On the lathe, boring is accomplished by either of the two methods following:

(a) Mounting the holder and boring tool bar with cutter bit on the toolpost and revolving the workpiece.

(b) Mounting the workpiece in a fixed position to the carriage and revolving the boring tool bar and cutter bit in a chuck attached to the headstock spindle.

(2) Boring is necessary in many cases to produce accurate holes or bores. Drilled holes are seldom straight due to imperfections in the material which cause drills to move out of alinement.

Therefore, where accuracy is important, drilled holes are usually made undersize and then bored or reamed to the proper dimensions. Boring is also useful in truing large holes in flat material. In this case, the hole is cut undersize with a welding torch or bandsaw, and is trued to proper dimension by boring.

b. Mounting workpiece for boring. The workpiece may be supported in a chuck or fastened to a faceplate for boring operations, depending upon the shape of the material to be machined. When boring is to be performed on the ends of long stock, the workpiece is mounted in a chuck and a steady rest is used to support the right end near the cutter bit. Some boring operations require the use of special chuck mounted mandrels to hold workpieces that cannot be successfully mounted otherwise.

c. Boring cutter bit setup.

(1) The cutter bit used for boring is similar to that used for external turning on the lathe. The bit is usually held in a soft or semisoft bar called a boring tool bar. The boring tool bar (fig 15) is supported by a cutting toolholder which fits into the lathe toolpost.

(2) Boring tool bars are supplied in several types and sizes for holding different cutter bits. The bit is supported in the boring tool bar at a 90°, 30°, or 45° angle, depending upon the nature of the workpiece being bored. Most general boring is accomplished with a 90° cutter bit (fig 15). The bit is mounted at a 30° or 45° angle to the axis of the boring tool bar when it is necessary to cut up to the bottom of a hole or finish the side of an internal shoulder. Note the relative size of the cutter bit and boring tool bar to the workpiece dimensions shown on figure 5. It is desirable that the boring tool bar be as large as possible without interfering with the walls of the hole. The cutter bit should not extend far beyond the boring tool bar and the bit should be as short as possible to be gripped securely in the bar yet not have the shank end protrude far from the bar.

(3) The cutter bits used for boring are shaped like left-hand turning and facing cutter bits. Greater attention must be given to the end clearance angle and the back rake angle because of the curvature of the hole.

(4) The boring tool bar should be clamped as close to the holder and toolpost as possible considering the depth of boring to be done. The bar will have a tendency to spring away from the workpiece if the bar overhangs the toolpost too far. If deep boring is to be performed, it will be necessary that the bar be as large as possible to counteract this springing tendency.

d. Straight boring operation.

(1) The cutter bit is positioned for straight boring operations with its cutting edge contacting the workpiece approximately 5° above center (fig 57). The cutting edge faces forward for most

operations so that the lathe can turn in its normal counterclockwise direction. If for a special operation it becomes necessary to position the cutter bit against the rear wall of the hole, a right-hand turning cutter bit is used and the spindle rotation is reversed.

(2) Position the cutter bit so the cutting edge is immediately to the right of the workpiece and clears the wall of the hole by about 1/16 inch. Traverse the carriage by hand without starting the lathe to move the cutter bit and boring tool bar into the hole to the depth of the intended boring and out again to ascertain whether there is sufficient clearance to prevent the back of the cutter bit and the boring tool bar from rubbing the inside of the hole. When the clearance is satisfactory, position the cutter bit to the right of the workpiece ready for the first cut.

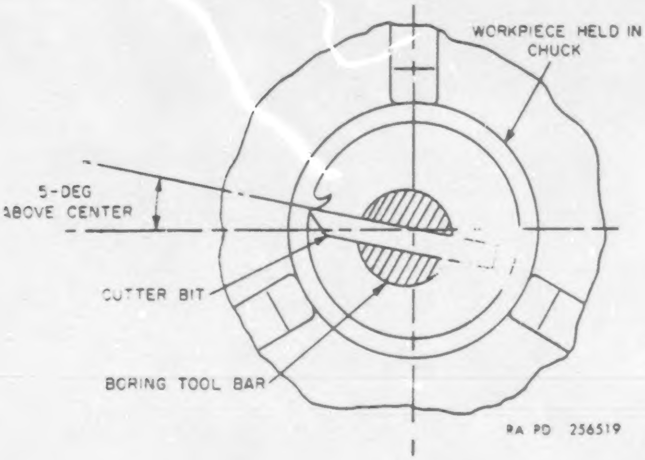


Figure 57. Cutter bit position for straight boring.

(3) The same speeds and feeds recommended for straight turning should be used for straight boring. It is often advisable to feed the cutter bit into the hole to the desired depth and then reverse the feed and let the cutter bit move out of the hole without changing the depth of feed. This practice will correct any irregularities caused by the bit or boring tool bar springing because of the pressure applied to the bit.

e. Taper boring operation.

(1) Taper boring is accomplished in the same manner as taper turning. However, only two of the three methods of taper turning are applicable—using the compound rest and using a taper attachment. As with taper turning, the compound rest can only be used for short, steep tapers since the movement of the compound rest is limited.

(2) The clearance of the cutter bit shank and boring tool bar must be determined for the smaller diameter of the taper. As with turning external tapers, it is also necessary to position the cutting edge exactly on the horizontal centerline of the workpiece, not 5° above center as with straight boring.

f. Internal thread cutting.

(1) Internal threads are cut in nuts and castings by the same general methods used in external thread cutting.

(2) The internal threading operation will usually follow a boring operation, and therefore the same workpiece holder can be used without disturbing the setup. Only the lathe speed will have to be changed to those recommended for external threading.

(3) The clearance of the cutter bit shank and boring tool bar to prevent rubbing must be greater for threading than for straight boring because of the necessity of moving the bit clear of the threads when returning the bit to the right after each cut.

(4) The compound rest should be set at a 29° angle to the saddle so that the cutter bit will feed after each cut forward and to the left (fig 58).

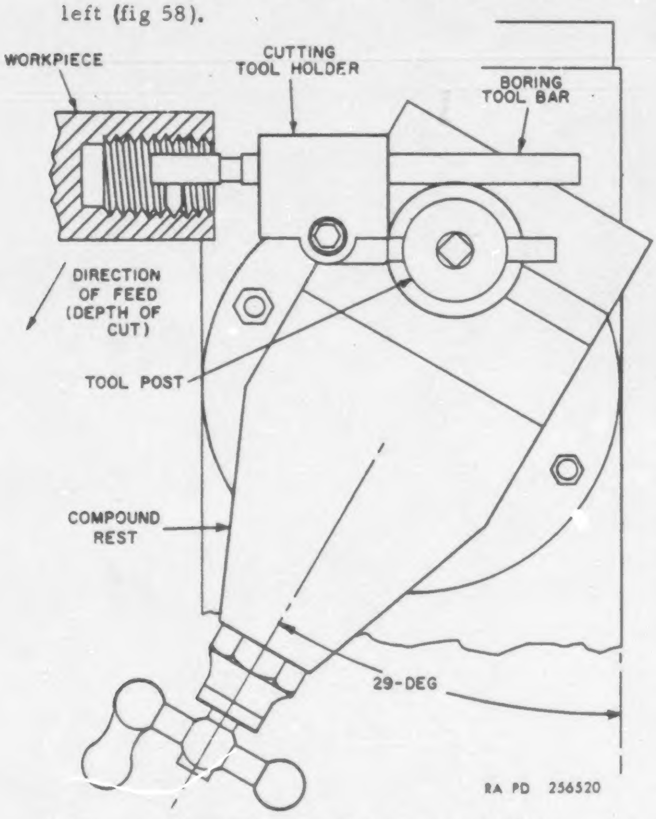


Figure 58. Setup for internal threading.

31. ECCENTRIC TURNING.

a. General. Eccentric means off-center and applied to lathe operations, refers to turning a section of the workpiece which has a different axis than the main body of the piece. The principle of eccentric turning on the lathe is to set up the piece so that the portion of the workpiece to be turned is axially alined with the headstock and tailstock spindles.

b. Mounting work for eccentric turning.

(1) A good example of eccentric turning is the turning of a crankpin on a crankshaft (fig 59). The main journals are on one axis while the crankpin is on another axis several inches from the main journal axis. The main journals can be machined in the same manner as bar stock by centering and drilling the ends of the journals and setting the crankshaft in the lathe. To machine the crankpin, it is necessary to revolve the crankshaft about the crankpin axis. This is accomplished by using adapters (fig 59) on the ends of the main journals to permit proper mounting of the crankshaft so that the crankpin can be turned.

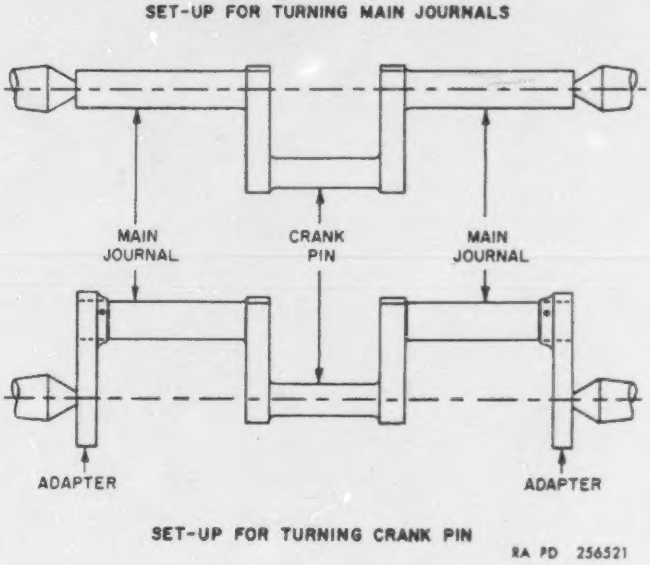

SET-UP FOR TURNING MAIN JOURNALS
MAIN JOURNAL
CRANK PIN
MAIN JOURNAL
ADAPTER
ADAPTER
SET-UP FOR TURNING CRANK PIN
RA PD 256521

Figure 59. Example of eccentric turning.

(2) If the workpiece cannot be mounted successfully between centers, it can be mounted in an indpendent chuck or fastened to a faceplate. In either case, it is necessary to true the portion to be turned eccentrically and not the major portion of the piece. In some cases, it will be necessary to counterbalance the workpiece if the piece is mounted appreciably off balance.

c. Eccentric turning operation. Once the workpiece is set up correctly, it is turned in the same manner prescribed for straight turning. In the example of the crankshaft (b(1) above), the cutter bit, cutting toolholder, and compound rest must be positioned so that the swinging main journals will not contact any part of the lathe or equipment. In the particular example, two cutter bits, a left-hand turning cutter bit, and a right-hand turning cutter bit would be used for turning the crankpin so that the pin could be turned out to the edges without interfering with the swinging main journals.

32. FILING AND POLISHING.

a. General. Filing and polishing are performed in the lathe to remove toolmarks, reduce the dimension slightly, or improve the finish.

b. Filing.

(1) Mill files are generally considered best for lathe filing. The bastard cut mill-type hand file is used for roughing and the second cut mill-type hand file for the finer class of work. Other types such as the round, half-round, and flat-hand files may also be used for finishing irregular shaped workpieces.

(2) For filing ferrous metals, the lathe-spindle speed should be four or five times greater than the rough turning speed. For filing nonferrous metals, the lathe-spindle speed should be only two or three times greater than the roughing speed. Too slow a speed may cause the workpiece to be filed out-of-round, while too high a speed will cause the file to slide over the workpiece, dulling the file and glazing the piece.

(3) The file is held at an angle of about 10° to the right and moved with a slow motion from left to right so that the teeth will have a shearing action. The direction of stroke and angle should never be the opposite, as this will cause chatter marks on the piece. The file should be passed slowly over the workpiece so that the piece will have made several revolutions before the stroke is completed.

(4) The pressure exerted on the file with the hands should be less than when filing at the bench. Since there are less teeth in contact with the workpiece, the file must be cleaned frequently to avoid scratching.

(5) Since filing should be used for little more than to remove toolmarks from the workpiece, only 0.002 to 0.005 inch should be left for the filing operation.

c. Polishing.

(1) Polishing with either abrasive cloth or abrasive paper is desirable to improve the surface finish after filing. Emery abrasive cloth is best for ferrous metals while abrasive paper

often gives better results on nonferrous materials. The most effective speed for polishing with ordinary abrasives is approximately 5,000 feet per minute. Since most lathes are not capable of a speed this great for average size workpieces, it is necessary to select as high a speed as conditions will permit.

(2) In most cases the abrasive cloth or paper is held directly in the hand and applied to the workpiece, although it may be tacked over a piece of wood and used in the same manner as a file. Improvised clamps may also be used to polish plain round work.

(3) Since polishing will slightly reduce the dimensions of the workpiece, 0.00025 to 0.0005 inch should be allowed for this operation. The use of oil with the abrasive will produce a satin finish, while dry polishing will leave a bright surface. Crocus cloth may be used after the abrasive cloth or abrasive paper to produce a higher luster on the surface.

33. GENERAL. The special lathe operations described in the remainder of the lesson are normally performed on machine tools other than the lathe, but can be and often are performed on the lathe. These operations include drilling, reaming, tapping and die cutting, and milling.

34. DRILLING WITH THE LATHE.

a. General. Drilling is done in the lathe by either of two methods, by revolving the workpiece in the lathe chuck with the twist drill held in the tailstock, or by revolving the twist drill in a chuck in the headstock and supporting the workpiece with some attachment such as V-center in the tailstock.

b. Methods of supporting twist drill in the tailstock.

(1) Straight-shank twist drills are usually held in a drill chuck (fig 60) which is placed in the taper socket of the tailstock spindle. Combination drill and countersinks can also be supported in this way.

(2) Taper-shank twist drills may be held directly in the tailstock spindle as long as they have a good fit. For this purpose, drill sockets or drill sleeves can be used to reduce the taper socket in the tailstock spindle to the proper taper and size of the twist drill.

(3) An expedient method of supporting a large twist drill in the tailstock is to fasten a lathe dog (fig 61) to the drill shank and support the rear of the drill with the tailstock center in the center hole in the tang of the drill. The lathe dog should rest against the cross slide or compound rest. The drill must be supported by hand until it is held secure by the pressure between the tailstock center and the workpiece. When this method is used, never withdraw or loosen the tailstock spindle while the lathe is in operation. To withdraw the drill, it is necessary to stop the lathe completely.

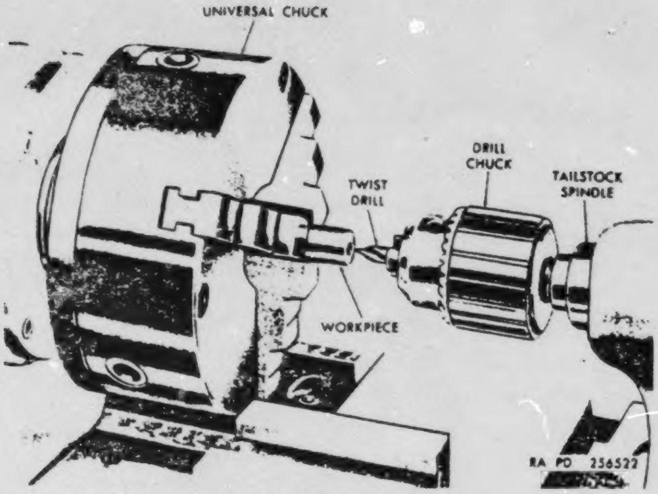

UNIVERSAL CHUCK
DRILL CHUCK
TWIST DRILL
TAILSTOCK SPINDLE
WORKPIECE
RA PD 256522

Figure 60. Drilling workpiece in the lathe.

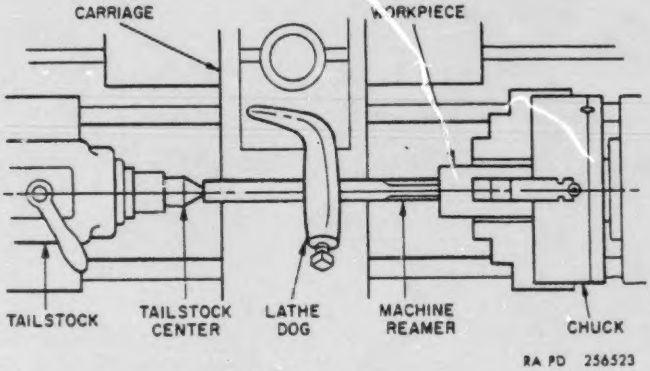

CARRIAGE
WORKPIECE
TAILSTOCK
TAILSTOCK CENTER
LATHE DOG
MACHINE REAMER
CHUCK
RA PD 256523

Figure 61. Reaming on the lathe.

c. Methods of supporting drill in headstock.

(1) Straight-shank twist drills are supported in the headstock by a drill chuck mounted in the headstock spindle.

(2) Taper-shank twist drills can be mounted in the headstock by placing the drill in a drill socket or sleeve which has a cylindrical outer surface like the spindle of a drilling machine. The socket or sleeve is then fastened in a universal or independent chuck. If the taper shank of the drill is compatible with the taper socket in the headstock spindle, the drill can be mounted directly.

d. Mounting the workpiece for drilling.

(1) If the workpiece is to be rotated and the twist drill is to be fed into the workpiece with the tailstock spindle, the piece may be mounted in a universal chuck (fig 62), independent chuck, or to a faceplate. The center of the hole to be drilled should be accurately marked and punched as described for drilling machine setups.

(2) Before drilling, check the centering of the punchmark by using a center indicator. The drill will not cut accurately unless the punchmark indicating the hole coincides exactly with the axis of the headstock spindle.

(3) If the twist drill is to be rotated by the headstock spindle and the workpiece is to be supported by a V-center, the piece should be carefully positioned by hand and the drill moved lightly into contact with the piece before the lathe is started. The piece must be well supported during drilling operations to prevent the piece from rotating with the drill.

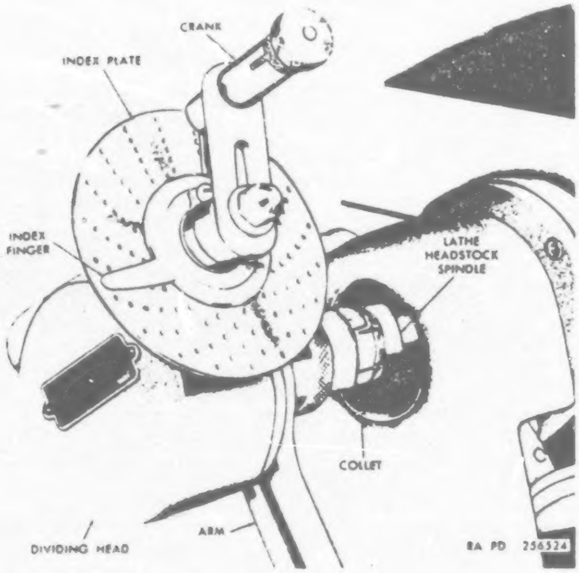


Figure 62. Dividing head of the milling and grinding lathe attachment installed on the lathe.

e. Drilling operation (fig 60).

(1) The spindle speed in revolutions per minute is determined by the size of twist drill for a particular material and will be the same for a particular drill size whether the drill is revolved or the workpiece is revolved.

(2) The feed is controlled by turning the tailstock hand screw. The graduations on the tailstock spindle are used to determine the depth of cut.

(3) If large size twist drills are to be used, the drill should be preceded by a lead drill, the diameter of which must not be greater than the thickness of the web of the large drill.

35. REAMING WITH THE LATHE.

a. General. Reamers are used to finish drilled holes or bores quickly and accurately to a specified diameter. When a hole is to be reamed, it must first be drilled or bored to within 0.004 to 0.012 inch of the finished size since the reamer is not designed to remove much material.

b. Machine reaming.

(1) The hole to be reamed with a machine reamer must be drilled or bored to within 0.012 inch of the finished size so that the machine reamer will only have to remove the cutter bit marks.

(2) The workpiece is mounted in a chuck at the headstock spindle and the reamer is supported by the tailstock in one of the methods described for holding a twist drill in the tailstock. Figure 61 illustrates the machine reamer supported by a lathe dog and tailstock center.

(3) The lathe speed for machine reaming should be approximately one-half that used for drilling.

c. Hand reaming.

(1) The hole to be reamed by hand must be within 0.005 inch of the required finished size.

(2) The workpiece is mounted to the headstock spindle in a chuck and the headstock spindle is locked after the piece is accurately set up. The hand reamer is mounted in an adjustable tap and reamer wrench and supported with the tailstock center. As the wrench is revolved by hand, the hand reamer is fed into the hole simultaneously by turning the tailstock handwheel.

(3) The reamer should be withdrawn from the hole carefully, turning it in the same direction as when reaming. Never turn a reamer backward.

36. TAPPING AND DIE CUTTING THREADS.

a. General. Internal and external threads are often cut on the lathe by means of taps and dies. The advantage of tapping and die cutting on the lathe over doing it on the bench is that the tap or die can be centered accurately so that the threads produced are generally more accurate in regard to the axis of the workpiece.

b. Tapping threads on the lathe. Threads may be tapped in the lathe by either of the two following methods:

(1) With the headstock spindle of the lathe locked and the workpiece held in the chuck, the tap is placed in the workpiece bore and the tailstock center run against the countersunk end of the tap. The tap is turned by means of a fixed open end wrench while pressure is applied to it with the tailstock handwheel. This method is recommended for large taps and for material that does not machine easily.

(2) When tapping free-machining material, the tap may be held by an adjustable tap and reamer wrench, the handle resting against the compound rest of the carriage, and the tailstock center bearing against the countersunk end of the tap. The lathe is operated at very slow speed while constant pressure is maintained against the tap by means of the tailstock handwheel.

c. Die cutting on the lathe. When cutting threads with a die, the workpiece is usually held in the headstock and the die set on the workpiece with the die stock resting upon the compound rest of the carriage. The threads are cut in a similar manner to tapping by causing the lathe to revolve at a very slow speed while pressure is applied by means of the tailstock handwheel.

37. MILLING ON THE LATHE.

a. General. Milling operations may be performed on the lathe through use of the milling and grinding lathe attachment which, in effect, converts the lathe into a milling machine. The milling and grinding lathe attachment (fig 27) contains a mechanism for vertical adjustment of the milling head but utilizes the carriage and feed controls of the lathe to move the milling head in a horizontal direction. A dividing head supplied with the attachment is installed on the headstock spindle of the lathe to permit indexing of the workpiece. Although the workpiece is mounted in a conventional manner in the lathe, the headstock spindle is never rotated by power for milling functions. Cutting is done by the milling cutter which is mounted to the milling head of the milling and grinding lathe attachment and driven by the self-contained electric motor of the attachment.

b. Mounting workpieces for milling on the lathe. Workpieces are supported in the lathe between centers, against a faceplate, or in a chuck fixed to the headstock spindle. A lathe dog is used to secure the workpiece to the driving faceplate if the workpiece is mounted between centers. If long workpieces are chuck mounted, a steady rest or a follower rest is used to support the free end of the workpiece.

c. Indexing workpieces for milling on the lathe.

(1) Indexing is the process of controlling the rotational position of a workpiece which is mounted axially. Workpieces mounted in the lathe for milling with the milling and grinding lathe attachment are indexed with the dividing head, a part of the attachment.

(2) The dividing head (fig 62) attaches to the left end of the lathe headstock and connects to the lathe headstock spindle with a collet. With the dividing head affixed to the headstock and headstock spindle, the spindle will not rotate freely but will move when the crank of the dividing head is turned. Forty turns of the crank will move headstock spindle through one complete revolution. Index plates containing concentric rings of evenly spaced holes fasten to the index plate beneath the crank. Each concentric ring has a different number of holes per circle, and each index plate has six concentric rings.

(3) The workpiece is indexed by moving the crank (fig 62) from one hole in the index plate to another. An index finger (fig 62) can be set to indicate a certain number of holes thereby making the counting of individual holes unnecessary.

d. Milling operation (fig 63). Plain milling, angular milling, face milling, form milling, keyway milling, spline milling, gear cutting, and drilling and boring operations can be successfully performed on the lathe by using the milling and grinding lathe attachment.

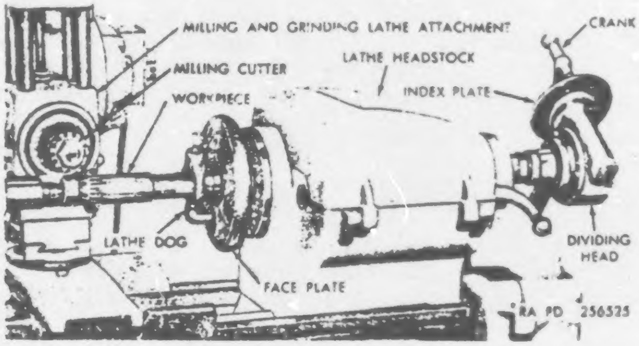


Figure 63. Milling operation on the lathe.

(1) The basic difference between milling on a horizontal milling machine and milling with the milling and grinding lathe attachment is that with the milling machine the worktable reciprocates beneath a milling cutter, while with the attachment the milling head feeds along the stationary workpiece.

(2) Milling cutter speeds and worktable feeds should be consistent with those speeds and feeds recommended for milling machine operation.

(3) Select a cutting speed consistent with the material being milled. If the recommended speed cannot be matched by one of the available speeds of the milling and grinding lathe attachment, select the next lower speed.

(4) If a coolant attachment is available, flood the milling cutter and workpiece contact area with an appropriate cutting oil. If a coolant attachment is not available, apply a cutting oil generously from a hand oiler during operation.

38. SUMMARY. This lesson has discussed the origin, development, and advancement of the lathe. You have learned that lathes can be conveniently classified as engine lathes, turret lathes, and special purpose lathes. The purpose and uses of each type lathe were discussed. You now know the common types of cutter bits and their application. You also have learned how to mount the various cutter bits. You are aware of the fact that workpieces are held to the headstock spindle of the lathe with chucks, facepieces, or lathe centers. The uses of mandrels, rests, and lathe dogs were discussed. You have been oriented on the toolpost grinding machine and the milling and grinding lathe attachments. The methods of laying out work for the lathe were presented. There was a discussion covering the mounting of workpieces between centers, in chucks, to facepieces, and on mandrels. Lathe speeds and feeds and the use of cutting oils were covered. You now know the meanings of facing and the various types of turning and parting. Screw threads and screw thread cutting were discussed. Boring with the lathe was defined and the procedures outlined. Information pertaining to eccentric turning and filing and polishing was presented. Special lathe operations such as drilling, reaming, tapping, and die cutting, normally performed on machine tools other then the lathe, were explained. You have learned that the lathe is one of the most valuable and versatile machines in your shop. The information presented in this lesson should serve you well as you practice your trade as a machinist.

EXERCISE

116. Which unit of measurement is used to measure the distance between centers on a lathe?

a. Inches
b. Feet
c. Millimeters

117. What is the purpose of the back gear on the headstock spindle of a lathe?

a. Decrease speed
b. Reverse direction of rotation
c. Increase speed

118. What material would require a 30° back and side rake clearance angle on the cutter bit for a lathe?

a. Soft steel
b. Laminated plastic
c. Cast plastic

119. What is the MOST desirable radius (inches) on the nose of a tool bit used for general shaping and finishing?

a. 1/4
b. 1/8
c. 1/32

120. What determines the width of the flat at the nose of the tool bit when cutting National screw threads?

 a. Pitch of thread
 b. Thread angle
 c. Radius of stock

121. Which cutter bit must be ground on a dry standard grinding wheel?

 a. Tungsten carbide
 b. Carbon steel
 c. High speed steel

122. Which chuck is used to hold a workpiece in an eccentric position?

 a. Independent
 b. Offset
 c. Step

123. Which lathe component is used to provide a firm connection between the headstock spindle and the workpiece mounted between centers?

 a. Dog
 b. Center
 c. Faceplate

124. Which material is used to make scribed lines visible on the surface of a workpiece?

 a. White lead
 b. Prussian blue
 c. White paint

125. How is the tailstock center distinguished from the headstock center?

 a. Tang
 b. Taper
 c. Groove

126. Which operation is correct when grinding lathe centers on the lathe?

 a. Workpiece and grinding wheel must be rotated in opposite directions at point of contact
 b. Workpiece turns the same speed as the grinding wheel
 c. Grinding wheel turns counterclockwise—workpiece turns clockwise

127. Which lubricant should be used on dead center of a lathe?

 a. Vaseline and soda water
 b. White lead and oil
 c. Crude petroleum

128. What percent can the recommended speed be increased if cutting oil is used on a high speed steel cutter bit?

   a. 75 to 100
   b. 50 to 75
   c. 25 to 50

129. For straight turning on a workpiece, which tool bit is especially efficient for finishing cuts?

   a. Roundnose
   b. Facing
   c. Thread

130. What is the TPF (taper in inches per foot) of a workpiece 3 feet long, 6 inches in diameter at one end, and 3 inches in diameter at the other end?

   a. 1/3
   b. 2/3
   c. 1

131. What is the most common method used for turning steep tapers?

   a. Taper attachment
   b. Compound rest
   c. Offset tailstock to right

132. What type screw thread is esp[illegible] suitable for vise or jack screws?

   a. Square
   b. Acme
   c. American Standard

133. How should the cutter bit be set when cutting a taper thread?

   a. Right angles to axis of workpiece
   b. Same angle of taper as workpiece
   c. Right angles to taper of thread

134. What lathe component can be used for taper boring?

   a. Taper attachment
   b. Offset tailstock
   c. Follower rest

135. In reference to reamers, which statement is correct?

   a. Reamer should be withdrawn from the hole by turning it in the opposite direction as when reaming
   b. Reamer should be withdrawn from the hole by turning it in the same direction as when reaming
   c. Lathe speed for machine reamers should be approximately twice that for drilling

370

EXERCISE RESPONSE LIST

SUBCOURSE 424
MACHINE SHOP PRACTICE

OCTOBER 1973

.DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND
MARYLAND

NOTICE

The inclosed responses are listed in numerical order. After making a circle around the number of your choice on the ANSWER SHEET, check the same number on the exercise response list. If you selected the correct answer, the response will indicate it with the word "CORRECT" appearing as the first word. Read the response for further information and then proceed to the next question. If the response shows you have not selected the correct choice, read the information presented to find out why your choice was wrong and where you can find the correct answer. The suggested references are designed to cover major teaching points in each lesson, thus reinforcing the student's learning process.

REMINDER!! Be sure to PRINT your name, grade, social security account number, subcourse number, and date in the top left corner of your answer sheet before you start your first exercise.

RESPONSE NUMBER	RESPONSE
100	This is true. Heavy pressure on the side of the grinding wheel may crack it and create a safety hazard. Refer to paragraph 28a(2) for the proper method of detecting faulty grinding wheels and select another answer.
101	Brine is usually used for quenching plain carbon steels. Refer to paragraph 58b(3) and select another response.
103	CORRECT. Sometimes sulfur is added to basic open-hearth steel to make it free-machining. Recent attempts have also been made to add nitrogen as well.
104	Part of this response is correct. Read paragraph 4a again to get the proper unit of measure.
106	CORRECT. The cutter bit is supported vertically in the cutting toolholder for surface cuts and is offset at an angle for down cutting operations.
108	CORRECT. The lathe headstock spindle is back-geared to provide slow spindle speeds.
109	Chips are formed and removed from metal while drilling. One of the advantages of spiral fluted drills is that the chips are so formed as to occupy the minimum amount of space. Scan paragraph 7a(2) and choose a more appropriate answer.
110	CORRECT. The definition of fatigue can be summarized by saying that it is the failure of metals and alloys that have had repeated or alternating stresses which were too small to produce a permanent deformation when applied statically.
111	CORRECT. The lathe is started at moderate speed and then the grinding machine. Make sure that the lathe and grinding abrasive wheel both rotate in the same direction (the workpiece and the wheel will be moving in opposite directions at the point of contact).
112	The addition of sulfur to basic open-hearth steel has no effect on the carbon content. Examine paragraph 30b again and choose another response.
113	The "M" on the front view represents surface "B" of the isometric drawing. Become better acquainted with paragraph 6b(11) and figures 21a and 22, then choose another answer.
115	CORRECT. The metal slitting saw milling cutter is essentially a very thin plain milling cutter. It is ground slightly thinner toward the center to provide side clearance. It is used for metal sawing and for cutting narrow slots.

116 This is the relationship existing between two or more mating parts with respect to the amount of clearance or interference which is present when they are assembled. Get a better interpretation of paragraph 7a(7)(d) and select another response.

117 You must have made a mistake in arithmetic. Refer to paragraph 2e(2)(b) and select another response after recomputation.

118 One turn of the index crank revolves the spindle 1/40 of a revolution (1/40 of 360°) or 9°. Therefore, 10 complete turns of the index crank would make the index head move further than this. Return to paragraph 13d, recompute the problem, and choose another answer.

119 CORRECT. Slag provides wrought iron with the property of resisting corrosion and oxidation. Wrought iron can be easily welded by any method.

121 The nose radius of a tool bit used for general shaping and finishing should be smaller. Reevaluate paragraph 5e and select another answer.

122 When you reexamine paragraph 3b you will find that medium bandsaw teeth cannot be sharpened. Choose another answer.

123 This is not the correct angle for the cutter bit when cutting a taper thread. You need a more thorough interpretation of paragraph 28j and the note to arrive at the correct answer.

124 The strength of a material is the property of resistance to external loads or stresses while not causing structural damage; malleability is the property of a metal which permits permanent deformation by compression without rupture. Study paragraph 9 again and select another response.

127 CORRECT. Multiply the number of strokes per minute by the length of the stroke in inches and then multiply the product by 0.14. In this case, 0.14 times 5 times 70 equals 49 feet per minute.

129 CORRECT. Computation of the solution is as follows:

$$b^2 = e^2 - a^2$$

$$b^2 = (155)^2 - (93)^2$$

$$b = \sqrt{15376} = 124$$

131 The ram on certain types of milling machines provides additional rigidity; however, this is not the main purpose of the ram. Evaluate paragraph 3b(4)(b) and choose another answer.

133 Special types of steel are manufactured by another process. Scan paragraph 28a and select another response.

134 Striding levels are machinists' bench levels especially adapted for spanning over obstructions. They are equipped with raised supports that provide the necessary room to clear obstructions. However, only one plane can be measured at a time. Review paragraph 19a(1) and select another response.

136 A speed of 75-150 (FPM) would result in an inefficient operation when cutting soft brass. The softer the material, the faster the speed should be. Reread paragraph 7b(4) and table III and then select another answer.

138 A pin punch is used for removing bolts or pins that have been unseated. Check paragraph 9d and select another answer.

139 You need a more thorough interpretation of paragraph 15c(1) before selecting another answer.

140 CORRECT. The universal milling attachment is similar to the vertical spindle attachment but is more versatile. The cutter head can be swiveled to any angle in any plane, whereas the vertical spindle attachment only rotates in one plane from horizontal to vertical.

141 Remember the method of obtaining the total reading; first, read the graduation on the main scale; second, locate the line on the vernier scale that corresponds with the line on the main scale; third, add the figures from the readings on the main scale and vernier scales for the total reading. Study paragraph 25c(5)(a) and figure 93, then choose another answer.

142 The proper back rake angle for cast plastic is 30° and the side rake angle is 25°. Scan paragraph 5 and table I to get the correct angles for laminated plastic.

143 This is SAE 2310 steel. The first digit (2) indicates nickel steel, the second digit (3) indicates the approximate percentage of alloying element nickel, and the third and fourth digits (10) indicate hundredths percent of carbon. Study paragraphs 25c and d and select another response.

144 CORRECT. Because the contact areas of the square screw threads are relatively small and do not wedge, friction between matching threads is reduced to a minimum under heavy pressure.

145 The blade tips of screwdrivers vary from a narrow parallel sided tip to a wide tapered tip; however, the sizes are determined by another factor. Review paragraph 11a and select another response.

147 CORRECT. The various interchangeable handles used with sockets are a ratchet, sliding tee bar, speeder, speed tee, and a nut spinner.

149 A 3-1/2-inch cutter would need a higher RPM in order to obtain 120 surface feet per minute. Scan paragraph 17 and table II and choose another response.

150 CORRECT. Double-cut files have two rows of parallel teeth which cross each other. The first row is cut at about a 45° angle and is coarser and deeper than the second row which is cut from 70° to 80°.

152 CORRECT. Computation of the solution is as follows:

$4y + 36 = 6z - 12$

$4y + 36 = (6)(2/3) - 12$

$4y = -48 + 4$

$y = -11$

154 CORRECT. As the workpiece becomes thicker, the file should be coarser to provide additional space for chips between the teeth.

156 CORRECT. The surfaces "F," "B," and "A" in the isometric drawing are represented by the letter "M" in the front view.

159 This is the approximate typical cutting speed for roughing and finishing copper. Refer to paragraph 10c and table II before choosing another answer.

161 CORRECT. A trammel is used for the same purposes as a divider or caliper, but usually for distances beyond the range of either of these two instruments. The instrument consists of a rod or beam to which trams may be clamped. The beams normally range in length from 9 to 12 inches.

164 The circular arc is dimensioned by using one-half the length of the diameter. See paragraph 7f and then select another response.

166 CORRECT. The energy recoverable from a clock spring, fishing rod, or similar items when the load is removed is an example of resilience.

167 Machined finishes should not be confused with finishes of chromium plating, enamel, and similar coatings. Check paragraph 9a and choose another response.

[illegible] Are you sure that you are using the proper formula or is your arithmetic incorrect? Refer to paragraph 27b(2) and recompute the problem, then choose another answer.

170 The long wearing, tungsten carbide point of the scriber must be sharpened by another method. Examine paragraph 20b(1) and choose another answer.

172 The slitting saw milling arbor is used on the milling machine to hold metal slitting saw milling cutters used for slotting, slitting, and sawing operations. Another type arbor is used for gear cutting. Refresh your memory of paragraph 5g and choose a more appropriate answer.

173 The size of a bench-type drilling machine is determined by another method. Evaluate paragraph 28e(1) and select another answer.

175 This blade would be too wide for cutting a 5/16 to 9/16 radius. Refer to paragraph 3e(5) and table II before choosing another answer.

177 Lip drills have four definite advantages. One of these is a correct rake to the lips. Examine paragraph 6a and choose another answer.

178 Carbon and other elements are eliminated when manufacturing wrought iron to leave almost pure iron. Check paragraph 37a again and choose another response.

179 The letters "G" and "H" in the orthographic views represent two different surfaces of the isometric drawing. Read paragraph 3 and look at figures 1, 2, and 3 to obtain the correct choice.

181 A cutter bit with a side clearance angle of 5° to 9°, a back rake of 2° to 10°, and a side rake angle of 16° to 20° would be suitable for roughing copper. Refer to paragraph 4c(3) and table 1 to determine the proper bit for roughing brass.

183 CORRECT. Usually the face of the thread cutter bit is ground flat and has clearances ground on both sides so that it will cut on both sides. For American (National) Standard screw threads, the bit is further ground with a flat nose.

184 This micrometer is used for taking inside dimensions. The average inside micrometer set has a range that extends from 2 to 10 inches. Review paragraph 23a(2)(c) and choose another answer.

186 CORRECT. The extension bar of the extension bar cutting toolholder should project forward from the toolholder shank only as far as required to permit the cutter bit to complete its cutting stroke.

188 A dimension line with its arrowheads shows the direction and extent of a dimension. Restudy paragraph 7 and figure 23 (orthographic views and isometric drawing), then choose another response.

190 The elimination of side thrust on the arbor is accomplished by another means. Read paragraph 4a(4)(a) and choose another response.

191 Orthographic prints are accurate and indicate true shape and size. These prints are usually drawn by orthographic projection. Refer to paragraphs 3 and 4 and figures 1 thru 6 before selecting another response.

192 Your first step in solving this problem is to find the total square feet to be painted. Refer to paragraph 2e(2)(b) and select another response after recomputation.

193 CORRECT. Forty turns of the index crank will turn the spindle one full turn; 1/12 x 40 = 3.33 turns of the crank after each cut for spacing the gear for 12 teeth.

194 CORRECT. Blades with fine teeth are best for sawing such materials as thin-walled tubing, conduit, and sheet metal thinner than 18 gage.

195 This is the fact, quality, or state of being variable. Refer to paragraph 8a and choose another response.

197 The monotron machine cannot conveniently be moved. The basic difference between it and other testing machines is that the depth of impression is kept constant and the pressure readings are the basis for the degree of hardness. Check paragraph 19 again and select another answer.

198 Another type tool bit is more efficient for this purpose. Turn to paragraph 24c for the correct answer.

199 This process is not similar to milling. Reread paragraph 2a and then choose another answer.

200 The circumference rule supplied by Army ordnance is 36 inches long, 1-1/4 inches wide, and 1/16 inch thick. A maximum circumference of 113 inches can be measured with it. Refer to paragraph 21a(1)(e) and select another response.

202 CORRECT. The size of a shaper is designated by the maximum length of its stroke; thus, a 16-inch shaper will machine workpieces up to 16 inches in length.

204 This fit has limits of size so prescribed that clearance always results when mating parts are assembled. Refer to paragraph 7a(7)(d) for the correct response.

205 The bench and pipe vise has integral pipe jaws for holding pipe from 3/4 inch to 3 inches in diameter. The maximum working main jaw opening is usually 5 inches. Evaluate paragraph 12a(3) and select another response.

206 The single open end adjustable wrench is similar in shape to the fixed end nonadjustable open end wrench, but it has one adjustable jaw and one stationary jaw. Scan paragraph 3d(3) and figure 10, then select another response.

207 The diamond point chisel is used for cutting V-grooves and sharp corners. Refer to paragraph 8e and select another response.

209 CORRECT. This information is obtained by interpreting paragraph 17 and table II.

210 CORRECT. To arrive at the proper measurement reading with a 6-inch micrometer, the three readings are totaled.

212 CORRECT. Using the engraving scale on the ram, the toolhead is set to the complement of the angle to be cut (90° minus the angle to be cut).

213 You are attempting to find the square root of 7.29. Work the problem again using the instructions in paragraph 2d(2) and then select another response.

215 CORRECT. Surface "C" of the isometric drawing is represented by the letters "G" and "Y" in the orthographic views.

216 This much increase would damage the high speed steel cutter bit. Refer to paragraph 21b(2) and table II for the recommended percentage of increase.

217 CORRECT. This firm connection permits the workpiece to be driven at the same speed as the spindle under the strain of cutting.

218 Some screwdrivers have special tips for cross-slotted recessed screws or bolts and clutch-bit screws. Special screwdrivers are provided with a ratchet arrangement. However, the size of a specific screwdriver is determined by another factor. Refer to paragraph 10a and choose another answer.

220 CORRECT. Measurements are transferred to the work by scribing a line. This gage is also used to indicate the accuracy or parallelism of surfaces.

222 Concave milling cutters are formed tooth cutters shaped to produce concave contours of one-half circle or less. Refer to paragraph 4a(4)(c)2 and choose another response.

223 The strain test for distortion or deformation by applying an external force upon elastic is common; however, it is not as frequently used as another test. Read paragraph 4b again and select another response.

224 This is not quite true although the lathe headstock spindle has a related purpose. Study paragraph 4e again and select another answer.

225 CORRECT. Chalk should be rubbed into the file before starting.

227 The two outside isometric axes are sketched much closer to the horizontal than this. Study paragraph 17 and figure 47 before choosing another response.

228 The hook rule is convenient for setting calipers and dividers. It is equipped with a sliding hook which facilitates measuring from a shoulder. Refer to paragraph 25a(4) and choose another response.

229 Never turn a reamer backward when withdrawing it from the hole. Become better acquainted with paragraph 35e(3), then choose a different answer.

231 The manufacturing process and not the type of ore governs the properties of steel. Choose another response after reading paragraph 27c(2).

233 You can learn what type setting is used on most metal cutting bandsaw blades by turning to paragraph 3e. Then choose another response.

235 Coke is charged with ore to reduce ore to metal in the blast furnace. Study paragraph 28b and select another response.

236 When the carbon content of steel is below 0.85 percent, the upper and lower critical temperatures differ. Read paragraph 57e again and select another response.

238 Straight flute end milling cutters are generally used for milling soft or tough metals, while spiral flute cutters are used mostly for cutting steels. Turn to paragraph 4a(4)(b) to learn the type cutter that is ground slightly thinner toward the center. Select another response.

239 CORRECT. Finish marks (✓) are used to indicate surfaces that must be finished by machining. In manufacturing, during the finishing process, the required limits and tolerances must be observed.

241 CORRECT. Ductility involves both the elongation and diameter reduction of material.

242 The depth of the impression is measured when using the Rockwell hardness tester. Please turn to paragraph 20 and select another response.

243 Titanium is one of the stronger commercially pure metals, but it is not the strongest. Read paragraph 4e again and select another response.

245 CORRECT. An electric butt welder and grinding wheel are built into the metal cutting bandsawing machine column. Since the machine can weld and cut its own blade bands, internal cutting is possible.

247 CORRECT. The shaper rotary table consists chiefly of a circular table containing T-slots, table base, and [illegible] pin. Workpieces are clamped to the circular tabletop using T-bolts.

248 Although magnesium ranks third in abundance it is not as widely used as chromium. Look at paragraph 44b again and select another response.

250 The primary clearance angle is the angle of the band of each tooth measured from a line tangent to the centerline of the cutter at the cutting edge. Restudy paragraph 4a(2)(a).

252 CORRECT. A few drops of oil mixed with white lead should be applied to the center before the workpiece is set up; then the lathe should be stopped at intervals and additional oil and white lead mixture applied.

253 CORRECT. Phantom views are used to indicate alternate positions of parts of the item drawn, as well as repeated details, or the relative position of an absent part.

255 This is not a type chuck commonly used with the lathe. Turn to paragraph 7b(2) to learn which chuck is used to hold a workpiece in an eccentric position. Then select another response.

256 Perhaps you made a mistake in arithmetic. Check your computation and select another response. The reference is paragraph 2d(2).

258 This item cannot be used for taper boring. Reread paragraph 30e and then select the correct answer.

259 CORRECT. Computation of the solution is as follows:

$$\text{TAN A} = \frac{a}{b} \qquad b = \frac{a}{\text{TAN A}} = \frac{20}{.88214} = 22.67''$$

260 CORRECT. The try square is used constantly for laying out and determining whether edges and ends are true with adjoining edges and with the face of the work after it has been sawed, planed, or chiseled.

262 The left-hand side finishing cutter bit would normally move in another direction. Look at figure 3 to get the proper direction and then choose a more appropriate answer.

264 CORRECT. Computation of the solution is as follows:

X = width x length x height, or 18,000 = (30)(60)(H).

Two walls 10' x 30' and two walls 10' x 60' have a total surface area of 1,800 sq ft.

Thus, $\frac{1,800}{200}$ = 9 cans of paint and 10 - 9 = 1 can of paint.

266 The bench mounted horizontal metal cutting shaper is powered by a 1/3 horsepower electric motor which is connected to the hull gear by V-belts and pulleys. Another component of the shaper permits lateral and vertical movement of the table. Restudy paragraph 3b and then select another answer.

268 A flexible blade is best for sawing hollow shapes and metals of light cross section, such as channel iron, tubing, tin, copper, aluminum, or babbitt. Take a look at paragraph 5c(6) before choosing another answer.

271 This blade would be too coarse for cutting thin sheet metal stock. Reread paragraph 3d and then select another answer.

273 Cutter bits are made from standard sizes of bar stock to fit into cutting toolholders which, in turn, are fastened to the toolpost of the lathe. The radius of stock has no bearing on the width of the flat at the nose of this tool bit. Refer to paragraph 5e(7) for the correct answer.

274 Refresh your memory for reading dimensions by referring to paragraph 7; then take another look at the orthographic views and isometric drawing and select another response.

275 The most difficult operation in taper turning (by offsetting the tailstock) is determining the proper distance that the tailstock should be moved to achieve taper. The offset tailstock is not the most common method used for turning steep tapers. Reread paragraph 27d(1) for the correct answer.

276 A heavy film of white oxide forms on the molten surface of aluminum; however, this is not a major characteristic. Refer to paragraph 43i again and select another response.

277 Extension lines are used to show where numerical or other expressions are intended to apply. Scan paragraph 7, the orthographic views, and the isometric drawing, and then select another response.

278 The letter "O" in the front view represents the bottom of the jig block. Study paragraph 3 and figures 1, 2, and 3 before selecting another answer.

279 25.4 cm equals 1 inch. Refer to paragraph 2f(5)(b), work the problem again, and select another response.

281 The spiral or helix angle refers to the spiral deflection of the teeth of the milling cutter. Another angle prevents the teeth of the cutter from rubbing against the workpiece. Study paragraph 4a(2)(f) and select another answer.

282 This pitch would not be best for cutting 1/32-inch sheet metal stock. Reread paragraph 3d, then choose another answer.

284 Molten metal is removed when cutting metal with the acetylene torch. Acetylene is a highly combustible gas composed of carbon and hydrogen. Study paragraph 7a(2) and select another response.

286 CORRECT. When the cutter is over 3/4-inch wide the teeth are usually helical, which gives the tool a shearing action and requires less power, reduces chatter, and produces a smoother finish.

288 CORRECT. One of its many uses is as an alloying agent in steel and cast iron (0.25 to 0.35 percent) and in nonferrous alloys of nickel, copper, aluminum, and cobalt.

289 Slag is an impurity extracted from a furnace during the manufacture of iron and is simply dumped in most cases. It is of little value. Examine paragraph 27e(2) and choose another response.

290 The Rockwell test measures resistance to penetration similar to the Brinell test; however, the depth of impression is measured instead of the diameter. Study paragraph 16 again and select another response.

291 CORRECT. When male centers are supplied in pairs, the tailstock center is usually distinguished from the headstock center by a groove close to the tapered point.

292 Your arithmetic must be incorrect. Refer to paragraph 2g(7), check your computation, and select another answer.

293 CORRECT. The surface of low-carbon steel is hardened by using the case-hardening process. This hardening is accomplished by increasing the carbon content of the surface only.

295 This is incorrect. Refer to paragraph 2a(2)(b), recompute the problem, and select another response.

296 The RPM of the driving gear is slower. Turn to paragraph 2e(2)(b)(3), work the problem again, and choose another response.

298 Remember that when one angle other than the right angle and a side is known, the length of the other two sides can be found. Refer to paragraph 2h(3)(a), recompute the problem, and choose another answer.

299 The isometric drawing is the most commonly used and the most useful in making freehand sketches. However, it is difficult to use alone for complicated parts or structures. Refer to paragraph 4b and select another response.

300 The floor mounted engine lathe is equipped with a tension release mechanism for loosening the drivebelt. This allows quick changes to different pulley combinations for speed changes. The headstock spindle serves another purpose. Refer to paragraph 4e and choose another answer.

301 CORRECT. Milling is the process of machining flat, curved, or irregular surfaces by feeding the workpiece against a rotating cutter containing a number of cutting edges. It is identical to circular sawing.

303 CORRECT. The reamer should be withdrawn from the hole carefully turning it in the same direction as when reaming. Never turn a reamer backwards.

304 CORRECT. When making an isometric sketch you start by sketching three isometric axes 120° apart, using two angles of 30° and a vertical axis of 90°.

306 A nose radius of 1/4 inch is not the most desirable for general shaping and finishing. Examine paragraph 5e and choose another answer.

307 CORRECT. Key seat clamps are made of steel, are case-hardened, and weigh 1 ounce each. They are designed to transform a straight steel rule into a rule that can be used to lay out keyways on a cylindrical surface of a shaft.

309 CORRECT. Tungsten is the strongest one of the group of commercially pure metals consisting of tungsten, molybdenum, titanium, and nickel respectively.

311 CORRECT. Symbols are used to state the geometric characteristics that are being toleranced.

313 Thickness (feeler) gages are fixed in leaf form to permit the checking and measuring of small openings such as contact points, narrow slots, etc. They are usually made with 2 to 26 blades grouped into 1 tool and graduated in thousandths of an inch. Refer to paragraph 27b and then select another response.

316 CORRECT. The taper file tapers toward the point, is usually single cut, and has edges that are set and cut for filing the gullet between saw teeth.

318 This is not an advantage of helical teeth over straight teeth on a plain milling cutter. Read paragraph 4a(4)(b) to get an advantage, then select another answer.

320 Two-piece collet dies are used with a collet cap and collet guide. The die halves are placed in the cap slot and are held in place by the guide which screws into the underside of the cap. Refer to paragraph 14b(2) and then select another response.

323 Machined finishes should not be confused with grease, paint, and similar coatings. Study paragraph 9a and choose another response.

324 CORRECT. The solution is computed as follows:

25.4 cm = 1 inch

$$\frac{120}{25.4} = 4.7244$$

326 This is not the primary purpose of the blast furnace; however, impurities are eliminated from ore when manufacturing iron by this process. Study paragraph 28a again and select another response.

328 Excessive projection of the extension bar will increase the tendency for the cutter bit to chatter. Turn to paragraph 15b(1), then select another response.

329 Another component would be used for most drilling and some cutting operations. You need a more thorough interpretation of paragraph 8 before selecting another answer.

330 Aluminum is the most abundant metal in the earth's crust, but it is not as versatile and widely used as the alloy chromium. Study paragraph 44b again and select another response.

331 This operation is not correct. Please restudy paragraph 16b(8), then select another answer.

332 Your computation is not correct. Check paragraph 11b(3), get the proper formula, recompute the problem, and then choose another response.

333 Surface "N" of the front view is the same as surface "D" in the isometric drawing. Choose another response after studying paragraph 4b, figure 9, the orthographic views, and the isometric drawing.

334 This is not one of the materials used to make scribed lines visible. Evaluate paragraph 15c(1) and the note, then select another answer.

335 Another tool is best suited for boring. Find the correct answer in paragraph 26 and choose another response.

336 Scrap is the material rejected and discarded during the manufacture of metals and is useful only as material for reprocessing. Study paragraph 37a again and select another response.

338 CORRECT. The distance between centers, measured in inches, indicates the longest length of material that can be placed in the lathe.

339 CORRECT. Raker set tooth blades have one tooth bent to the right, the next tooth bent to the left, and the third tooth set straight. This setting results in a tooth cut wider than the thickness of the blade to prevent the blade from being pinched by the stock.

341 Perhaps you made a mistake in your computation. Check your arithmetic and select another response. The reference is paragraph 2e(2)(a)(4).

342 This is SAE 5013 steel. Restudy paragraphs 25d and e and select another response.

344 CORRECT. Before installing a wheel on the grinder, tap it lightly with a mallet. A ringing sound indicates that the wheel is satisfactory; a dull sound indicates that the wheel may be cracked.

346 Water cooling is necessary when grinding carbon steel bits to prevent them from losing hardness by overheating. Check paragraph 5g(3) again, then select another answer.

347 Turn back to paragraph 2h(4)(a), work the problem again, and choose another answer. Your procedure is apparently incorrect.

349 CORRECT. Refer to the isometric drawing for this dimension.

350 CORRECT. The best general purpose machinists' hammer is the ball-peen. The flat end of the head is called the face and is used for most of the hammering jobs you will have.

352 CORRECT. The principle of the softer the material the faster the speed applies in this instance.

355 The end milling arbor has a bore in the end in which straight shank end milling cutters fit and are locked in place by means of a setscrew. Another type arbor is used for gear cutting operations on a milling machine. Refresh your memory of paragraph 5g and choose a more appropriate answer.

356 The overall height of the jig block is not this great. Evaluate paragraph 7, figure 23, the orthographic views, the isometric drawing and then choose another response.

358 An auxiliary view is often necessary to clearly show the true shape and length of inclined surfaces or other features which are not parallel to any of the principal planes of projection. Examine paragraph 5b and figure 12 and choose another answer.

360 In paragraph 2b you will find the proper method of cooling the workpiece during the cutting operation. Select another response.

362 CORRECT. Oil which removes heat slowly, thereby reducing cracking, is used to quench low-alloy steels and thin sections of carbon steel.

363 There is a more important reason why a coarse file should be used on thick stock. Reexamine paragraph 4d(2) and choose another answer.

365 When you reread paragraph 3b you will find that this is not true. Make another choice.

367 CORRECT. Snips will not remove any metal when a cut is made. There is danger, though, of causing minute metal fractures along the edges of the metal during the shearing process.

368 Taper turning with a taper attachment, although generally limited to a taper of 3 inches per foot and to a set length of 12 to 24 inches, affords the most accurate means for turning or boring tapers. However, this method is not suitable for turning steep tapers. Reread paragraph 27d(1), then select another answer.

369 The purpose of normalizing is to refine the grain structure of metals and remove stresses to a lesser extent than annealing. Refer to paragraph 60a again and then select another response.

371 This has no bearing on the size designations of shapers. Reread paragraph 2b and choose another answer.

372 CORRECT. This reading certainly has tested your comprehension of the method of reading the vernier. First, you read the graduations on the main scale; second, you located the line on the vernier scale that corresponded with the line on the main scale; third, you added the figures from the readings on the main scale and vernier scale for the total reading.

374 This is the approximate typical cutting speed for roughing and finishing machine steel. Refer to paragraph 10c and table II, then choose another answer.

375 Strain is distortion or deformation resulting from the application of external force upon elastic material. Read paragraph 10 again and select another response.

376 CORRECT. This vise is clamped to the edge of a bench and its holding capacity is generally 1-1/2 to 2 inches. It does not have pipe holding jaws.

378 Pack carburizing is accomplished by placing work in a metal container and surrounding the work by a mixture of charcoal or barium, calcium, or sodium carbonates. The container is then sealed and heated for 1 to 16 hours at 1,700° F to 1,800° F. The work is then removed, quenched, and tempered. Read paragraph 63a(5) again and select another response.

379 The draftsman uses a revolved section to eliminate extra views of rolled shapes, ribs, and similar forms. Study paragraph 5e(5) and select another response.

381 The vertical spindle attachment converts the horizontal spindle of a vertical spindle. End milling and face milling operations are more easily accomplished with this attachment, due to the fact that the cutter and the surface being cut are in plain view. Read paragraph 10 again to get the nomenclature of the attachment that can be swiveled to any angle or plane, then choose another answer.

382 CORRECT. The upper and lower critical temperatures are the same for steel when the carbon content reaches 0.85 percent.

384 Six and one-third turns of the crank after each cut would space the crank for a larger number of teeth. Examine paragraph 13c(1)(b) and choose a more appropriate answer.

385 Another method is recommended for sharpening the tungsten carbide, long wearing, scriber point. Evaluate paragraph 20b(1) and choose another response.

387 A cutter bit with a side clearance angle of 5° to 90°, a back rake angle of 2° to 8°, and a side rake angle of 14° would be suitable for roughing cast iron. Refer to paragraph 4e(3) and table 1 to get the proper bit for roughing brass, then select another answer.

388 Another means is used to distinguish the tailstock center from the headstock center. The correct answer can be found in paragraph 16a(1) and the note. Choose another response.

389 Box end wrenches have fixed handles and either 6, 8, 12, or 16 points inside the head. The number of points determine the strength of the head; i.e., 6- and 8-point ones are heavy duty, 12 points medium, and 16 points light duty. Evaluate paragraph 3e and figure 9, then choose another answer.

390 This is the first step for finding the square root of 15. Read paragraph 2d(1), work the problem again, and choose another answer.

391 Oil quenching, which removes heat slowly thereby reducing cracking, is used to quench low-alloy steels and thin sections of carbon steel. Take another look at paragraph 60a and then select another response.

392 CORRECT. Outlines or visible lines should be used for all lines on the drawing representing visible lines on the object.

393 CORRECT. Drill bits having three or four flutes are used for following smaller drills or for enlarging cored holes and are not suitable for drilling into solid stock.

394 The "P" and "S" denote dimension lines and are located on the side orthographic view. A dimension line with its arrowheads shows the direction and extent of a dimension. Study paragraph 7, the orthographic views, the isometric drawing, and then choose another response.

396 CORRECT. The rapid and simple Bessemer purification process was the first to give large quantities of cheap steel to the world. It inaugurated the "Age of Steel" in civilization.

397 The perspective drawing excels all other types of projection in the pictorial representation of objects. It is called the geometry of photography illustration work. Scan paragraph 4b and make another selection.

398 CORRECT. The solution is computed as follows:

$$\text{T.P.F.} = \frac{D1 - D2}{L} = \frac{6 - 3}{3} = 1'' \text{ per foot.}$$

399 This chuck is intended for very accurate holding of workpieces larger than 1 inch in diameter. Turn to paragraph 7b(2) to get the type used for an eccentric position, then make another selection.

400 This speed would be too slow for cutting soft brass and would result in an inefficient operation. Evaluate paragraph 7b(4) and table IX before selecting another response.

402 Open end wrenches have fixed handles and are usually double ended, although some have single openings. Reread paragraph 3e and figure 8, then select another answer.

403 A square file tapers slightly toward the point on all four sides and is double cut. Double-cut files have two sets of diagonal rows of teeth. On the top of the overcut set a second set is made crossing the first. The second set is called the upcut and is not as coarse or as deep as the overcut. Refer to paragraph 4e(8) and select another response.

404 Another unit of measure is used to measure the distance between centers on a lathe. Refer to paragraph 4a for the correct unit, then choose another response.

405 An attachment for the metal cutting bandsawing machine twists the bandsaw blade 30° or 90° so that stock which normally could not be cut because of insufficient clearance of the sawing machine column can be successfully cut. Examine paragraph 2b and choose another answer.

407 CORRECT. Screwdrivers are made in various shapes and lengths to perform specific jobs. The size is indicated by the length of the blade; i.e., a 6-inch screwdriver has a 6-inch blade.

408 The "N" on the front view represents surface "D" of the isometric drawing. Examine paragraph 6b(11) and figures 21a and 22 before making another selection.

409 Coke is charged with ore to reduce ore to metal in the blast furnace. Reread paragraph 28b and select another response.

410 You apparently made an error in arithmetic. Refer to paragraph 13e, recompute the problem, and choose another answer.

411 CORRECT. Straight turning is accomplished with the left-hand turning cutter bit, the right-hand turning cutter bit, or the roundnose turning cutter bit.

412 CORRECT. The isometric drawing is the most useful in freehand drawings. All lines that are parallel on the object are also parallel on the drawing.

414 CORRECT. Cutters with faces less than 3/4-inch wide are sometimes made with staggered or alternate right- and left-hand helical teeth. The shearing action, alternately right and left, eliminates side thrust on the cutter and arbor.

415 This term does not apply when dimensioning a circle. Check paragraph 7f for the proper term and then select another answer.

416 A removed section is normally used to illustrate particular parts of an object. It is drawn like the revolved section with the exception of being placed at one side of the main drawing. Refer to paragraph 5c(5) and choose another response.

417 Slip joint combination pliers are most commonly used to hold or bend wires, small bars, and a variety of miscellaneous items. Review paragraph 10a(5) before choosing another answer.

419 Convex milling cutters are formed tooth cutters shaped to produce convex contours of one-half circle or less. Refer to paragraph 4a(4)(c)2 and choose another response

420 CORRECT. The ball usually used in this test is 10 millimeters in diameter, has an applied load of 500 kilograms for soft materials such as copper and brass, and 3,000 kilograms for materials such as iron and steel. The diameter of the resulting impression is measured.

421 Molybdenum is one of the stronger commercially pure metals; however, it is not the strongest. Refer to paragraph 4e again and select another response.

422 Drift punches, sometimes called "starting punches," have a long taper from the tip to the body. They are used for knocking out rivets after the heads have been chiseled off or for freeing pins which are "frozen" in their holes. Study paragraph 9d and then select another response.

423 You probably do not fully understand the proper computation procedures. Study paragraph 2a(2)(b), work the problem again, and select another response.

425 This wrench provides the dual means for breaking tight nuts or bolts loose as well as rapid removal. Read paragraph 3d and select another response.

426 This is the process whereby work is placed in a gastight retort, heated to 1,700° F, and natural or manufactured gas is passed through the retort until proper depth is obtained. Next, the work is heat-treated as in the pack process. Study paragraph 63a(5) and then select another choice.

427 Strain is defined as distortion or deformation resulting from the application of external force upon elastic material. Read paragraph 10 again and select another response.

429 This process is the least expensive method of eliminating, or partly eliminating, the different common impurities in pig iron. However, it was not the first to yield large quantities of steel. Please refer to paragraph 30b before making another selection.

431 The teeth of milling cutters are either right-hand or left-hand as viewed from the back of the machine. But the type of teeth does not determine the pitch of a milling cutter. Reexamine paragraph 4a(2)(a) and select another answer.

432 CORRECT. The square of the square root of 225 is 225.

225 = 15 and $(15)^2 = 225$.

434 Single-cut files have rows of parallel teeth extending across the face of the file at an angle. Examine paragraph 4b(1) to get the cut for all handsaw files, then choose another answer.

436 A lathe facepiece is a flat, round plate that threads to the headstock spindle of the lathe. Another device is used for the firm connection referred to. Take another look at paragraph 10a and then choose another response.

437 Surface "T" of the side view is represented by surface "F" in the isometric drawing. Refer to paragraph 4b, figure 9, the orthographic views, the isometric drawing, and then select another response.

438 This increase in speed is too large and would cause damage to the steel cutter bit. Turn to paragraph 21b(2) and table II for the recommended percentage of increase and the correct answer.

439 Collets for milling machines serve to step up or increase taper sizes so that small shank tools can be fitted into large spindle recesses. Collets are not required for most drilling operations. Evaluate paragraph 8 again and choose another response.

440 When you refer to paragraph 2b you will find that this answer is incorrect. Try another response.

442 The two outside isometric axes are sketched closer to the horizontal. Refer to paragraph 17 and figure 47, then make the correct choice.

444 The hardness of metals is measured by other means. Study paragraph 27b and select another response.

446 Workpieces can be mounted directly to the shaper table or held in a swivel vise, shaper rotary table, or indexing fixture attached to the shaper table. Return to paragraph 3b to learn which component permits lateral and vertical movement of the shaper table. Then choose a more appropriate answer.

447 You need a more thorough interpretation of paragraph 17 and table II in order to arrive at the correct answer. Please select another response.

448 CORRECT. Tungsten carbide scribers are used to lay out lines on very hard materials, such as hardened steel and glass.

450 This component is not used for taper boring. After reading paragraph 30e again, choose a different answer.

451 Workpieces are fastened to the shaper rotary table by another means. Review paragraph 7 and choose another answer.

452 CORRECT. Aluminum does not turn red before melting. It holds its shape until almost molten, then collapses suddenly.

454 CORRECT. The side finishing cutter bit may be either right-hand or left-hand and is used for finishing vertical cuts.

457 The jig block is higher than this. Examine paragraph 7, figure 23, the orthographic views, the isometric drawing, and then choose another response.

459 CORRECT. The universal horizontal milling machine is of the ram type. The milling machine spindle is mounted in a ram at the top of the column that can be moved in and out to provide crossfeed for milling operations.

460 Your selection is incorrect. Study paragraph 2b again and choose another response.

462 CORRECT. The fly cutter arbor is one of the most commonly used tools for boring. The other most commonly used one is the offset boring head.

463 The Rockwell hardness tester cannot easily be moved. This machine is very useful for testing exceptionally high surface hardness such as case-hardened or nitrided surfaces. Refer to paragraph 19 again and select another response.

465 When possible, dimension each feature in the view where it appears in profile or where its true shape appears. Review paragraph 7, figure 23, the orthographic views, the isometric drawing, and then select another response.

467 This thread is especially suitable for lathe lead screws and similar power transmitting uses; however, it is not the best type for vise or jack screws. Refer to paragraph 28c(6) for the correct answer.

468 CORRECT. Button dies can be used in either hand diestocks or machine holders. These round split adjustable dies are available in a variety of sizes to cut American Standard coarse and fine threads and the standard sizes of threads that are used in England and other European countries.

470 This has no bearing on the width of the flat at the nose of the bit when cutting National screw threads. The correct answer can be found in paragraph 5e(7). Choose another answer please.

471 CORRECT. Computation of the solution is as follows:

Diameter = 4"

Circumference = 4π

4 x 3.1416 = 12.5664 or 12.56

474 Read paragraph 4e(2) to get the proper method for reducing the tendency of hard particles to adhere to files, then choose a different answer.

476 CORRECT. However, do not set the thread cutter bit at right angles to the taper of the thread.

477 Three- or four-fluted drill bits are used for another purpose. Refer to paragraph 6a and select another response.

479 The use of this combination is not recommended. Refer to paragraph 16d(3) and choose another response.

480 The secondary clearance angle defines the land of each tooth and provides additional clearance for passage of cutting oil and chips. Another angle prevents the teeth of the cutter from rubbing against the workpiece. Study paragraph 4a(2)(f) before selecting another choice.

482 Reexamine paragraph 3; figures 1, 2, and 3; the orthographic views; and the isometric drawings. Note that the letters "R" and "H" (isometric views) represent surface "A" of the isometric drawing. A more appropriate response is required.

483 Toughness, the property of absorbing considerable energy before fracture, involves both ductility and strength. Study paragraph 8 again and select another response.

484 CORRECT. The independent chuck can be used to hold square, round, octagonal, or irregularly shaped workpieces in either a concentric or eccentric position due to the independent operation of each jaw.

485 The case-hardening process is not used on high-carbon steels. High-carbon steels are used for the manufacture of drills, taps, dies, springs, machine tools, etc, that are heat-treated after fabrication to develop hard structure. Please turn to paragraph 63 and select another response.

486 CORRECT. Ductility and strength jointly form the characteristic of toughness in a metal.

488 CORRECT. When curves or radii are to be cut on the bandsawing machine, the widest blade adaptable to the sharpest radius to be cut should be used. Narrow blades are much more easily broken than wide blades and should be used only when absolutely necessary.

490 Water, which removes heat rapidly sometimes causing cracking, is used only for quenching heavy sections of carbon steel. Study paragraph 58b(3) and select another response.

491 CORRECT. Surface "A," or the top of the jig block, in the isometric drawing is represented by the letters "H" and "R" in the orthographic views.

492 CORRECT. The basic difference between the monotron machine and other testing machines is that the depth of impression is kept constant. The readings of pressure are the basis for the degree of hardness.

493 CORRECT. A clearance fit is one having limits of size so prescribed that clearance always results when mating parts are assembled. In contrast, an interference fit is one having limits of size so prescribed that an interference always results when mating parts are assembled. A transition fit is the result of either a clearance or an interference fit.

496 Examine paragraph 7 and the isometric drawing and select another response. Dimension lines, extension lines, and numerals are used to indicate sizes when dimensioning.

497 CORRECT. The master precision level is equipped with two additional shorter tubes at right angles to the main vial. These serve in setting the true vertical while the level is being held at the side of the surface.

498 True position is indicated by another symbol. See paragraph 8e and figure 38 before selecting another response.

500 CORRECT. The broken out sectional views are used when the details would be very difficult to show with any other type of drawing.

501 Strain is distortion or deformation resulting from an external force acting upon an elastic material. Read paragraph 4a and select another response.

502 The cutter bit should be set at another angle for cutting a taper thread. You need a better interpretation of paragraph 28j and the note before making another choice.

503 CORRECT. To make the scribed lines visible the surface may be first lightly covered with pigment such as red lead or Prussian blue, or it may be treated with a light application of copper sulfate solution.

504 Diagonal cutting pliers have short jaws with the cutting edges at a slight angle. They are used for cutting soft wire and stock; also, for cutting cotter pins and for spreading the ends after the pin is inserted through a hole. Reread paragraph 10a(5) and select the correct response.

505 The symbol for roundness is similar. Examine paragraph 8e and figure 37 and then select another answer.

507 The most common kind of milling cutter is known as a plain milling cutter. It is merely a cylinder having teeth cut on its periphery for producing a flat horizontal surface (or a flat vertical surface in the case of a vertical spindle machine). Turn to paragraph 4a(4)(b) to learn which type cutter is ground slightly thinner toward the center. Select another response.

508 CORRECT. The soft-faced drift punch is made of brass or fiber and is used for such jobs as removing shafts, bearings, and wrist pins from engines.

510 This is not a characteristic of aluminum. Read paragraph 43i again and select another response.

512 CORRECT. This clearance prevents each tooth from rubbing against the workpiece after it makes its cut.

513 CORRECT. The crossrail, located across the front of the shaper frame, supports the shaper table and permits lateral and vertical movement of the table.

515 CORRECT. In addition, hot, high speed steel cutter bits must never be dipped into water or the bit will crack and the cutting edge will crumble.

516 The firm joint caliper belongs to a family of outside calipers which includes the spring, transfer firm joint, and adjustable firm joint. Scan paragraph 23a(2)(c) and choose a different response.

518 CORRECT. The nomenclature used for shaper cutter bits is the same as that for lathe cutter bits, and the elements of the cutter bit, such as clearance and rake angles, are in the same relative positions. See figure 5.

520 Limits are the maximum and minimum values prescribed for a specific dimension. Examine paragraph 8a and select another response.

521 CORRECT. The tempering process is used to induce toughness after steel has been hardened and is too brittle for ordinary purposes. Quench hardened steel is reheated to a temperature below the transformation range then cooled at a rate depending on the toughness desired.

522 CORRECT. These are prints that furnish complete information for construction and repair and they present an object in its true proportions.

523 CORRECT. The surface designated "U" on the side view is represented by "E" in the isometric drawing.

524 As the carbon content of steel approaches 1.7 percent, the upper critical temperature rises abruptly. Read paragraph 57e again and then make another choice.

526 You can learn what type setting is used on most metal cutting bandsaw blades by turning to paragraph 3e before making another choice.

527 The property of material to regain its original dimensions, upon removal of the external load, is known as elasticity. Read paragraph 4e again and select another response.

528 CORRECT. The speeds listed in table II may be increased by 25 to 50 percent if a cutting oil is used.

529 Adding sulfur to basic open-hearth steel does not affect corrosion resistance. Scan paragraph 30b again and then select another answer.

531 Wearing goggles is always a must when using the grinder. Refer to paragraph 28a(2) for the proper method of detecting faulty grinding wheels and select another answer.

533 CORRECT. Where space permits, a radius dimension line is drawn from the radius center with the arrowhead ending at the arc and the dimension between the arrowhead and the center.

535 This is not the proper method for classifying shaper size. Restudy paragraph 2b and then select another answer.

536 CORRECT. Ultimate strength is the unit stress, measured in pounds per square inch, developed by the maximum applied load that the material can resist without rupturing in a tensile test.

537 CORRECT. Computation of the solution is as follows:

```
  2.8          20
 √7.29          2
  4.           ──
 ────          40 trial divisor
  3.29          8
               ──
               48 correct division
```

But 8 x 48 = 384, hence 8 is too large.

```
  2.7          20
 √7.29          2
  4.           ──
 ────          40
  3.29          7
  3.29         ──
 ────          47       47 x 7 = 329.
     0
```

539 The jig block is much longer than this. Refer to paragraph 7 and the isometric drawing, then choose a more appropriate response.

541 The diameter of the impression is measured when performing the Brinell hardness test on materials. Read paragraph 20 and select another response.

543 The left-hand roughing cutter bit is used for the majority of roughing operations on cast iron and steel workpieces. Vertically supported roughing cutter bits are offset for another reason. Examine paragraph 4b(2)(a) again and select another response.

545 The cold chisel is the most common type and is used to cut rivets, split nuts, chip castings, and cut thin metal sheets. Study paragraph 8e, then select another answer.

547 CORRECT. The first digit (5) indicates the type of steel (chromium), the second digit (1) indicates LOW chromium alloy, and the last two digits indicate 0.30 hundredths of 1 percent carbon.

549 Remember that this is a 6-inch micrometer. To arrive at the correct reading: first, record the highest figure visible on the barrel; second, count the number of lines visible between the highest figure on the barrel and the thimble edge; third, take a thimble reading that coincides with or has passed the revolution or long line in the barrel. The total of these three readings is the measurement reading. Study paragraph 26c(1) and figure 97, then choose another answer.

551 Care must be taken not to excessively project the extension bar or the cutter bit will chatter. You can learn the correct amount of projection by referring to paragraph 15b(1). Then choose a different answer.

553 This blade is recommended for general use on solid stock, aluminum, babbitt, tool steel, high speed steel, cast iron, and so on. Study paragraph 5c(6) and select another response.

555 The tape rule is a ribbon of flexible steel that is wound into a flat metal case by pressing a button or pushing it in by hand. It cannot be used for laying out keyways on the cylindrical surface of a shaft. Examine paragraph 21a(1)(e) before selecting another answer.

556 One turn of the index crank revolves the spindle 1/40 of a revolution (1/40 of 360°) or 9°. Therefore, 10 complete turns of the index crank would move the index head much further than this. Please return to paragraph 13d, recompute the problem, and choose another answer.

557 Your computation is incorrect. The cutting speed is not this fast. Turn to paragraph 11b(3), recompute the problem, and choose another answer.

558 Are you sure that you are using the proper formula or is your arithmetic incorrect? Refer to paragraph 27b(2), recompute the problem, and make another choice.

559 This factor has no bearing on size determination. Refer to paragraph 28e(1) and choose another response.

561 This is not an advantage of helical teeth over straight teeth. Reexamine paragraph 4a(4)(b) and choose another answer.

562 With this process, the hardness is measured by the height of rebound of a diamond-pointed hammer after it has been dropped on the sample. Read paragraph 16 again and select another response.

563 The letters "M" and "L" in the orthographic views represent surface "B" of the isometric drawing. Study paragraph 3 and figures 1, 2, and 3 and then select another response.

565 CORRECT. Metal cutting bandsaw blades range from 6 to 32 teeth per inch. The finer tooth blades are used for sawing thin stock and the coarse blades used for sawing large stock and soft metals.

567 The angle of a lathe way is determined by using the combination square equipped with a protractor head. Evaluate paragraph 23b(1)(a) and select another answer.

569 The offset boring head is an attachment that fits the milling machine spindle and permits a single-edge cutting tool, such as a lathe cutter bit, to be mounted off center on the milling machine. Workpieces can be mounted in a vise attached to the worktable and can be bored with this attachment. Reread paragraph 10 to get the nomenclature of the attachment that can be swiveled to any angle or place. Then choose another answer.

570 Never attempt to enlarge holes by tipping drill bits sideways. This will cause breakage. Look again at paragraph 6a and select another answer.

572 When you recompute the problem you will find that side "b" is longer than this. Refer to paragraph 2b(4)(a), work the problem again, and choose another answer.

573 The square root must be squared. Study paragraph 2d(1), recompute the problem, and select another choice.

575 Bastard cut band files are usually used for filing steel and other hard metals on the bandsawing machine. They have between 12 and 24 teeth per inch. Examine paragraph 4b(1) to get the characteristic cut for all bandsaw files. Then make another selection.

577 The sum of the angles of a triangle is 180°. Check paragraph 2g(7), try solving the problem again, and select another choice.

578 CORRECT. Steel is basically an alloy of iron and carbon. The percentage of carbon is the most important single factor governing the properties and uses of steel. Carbon is added to the steel when it is in the molten state.

579 CORRECT. The first digit (1) indicates the type of steel (carbon steel in this case), the second digit (0) indicates the approximate percentage of alloying element, the last two or three digits indicate average carbon content in hundredths of one percent (0.20 hundredths of 1 percent carbon in this case).

580 The machinists' bench vise is large with rough jaws that prevent the work from slipping. It is usually bolt mounted to a bench. Study paragraph 12a(3) and select another response.

581 A larger ball bearing can be machined from a 4-inch cube of steel stock. Check the procedures in paragraph 2e(2)(a)4, work the problem again, and select another choice.

582 Hardness is a combination of a number of physical properties. Elastically stressed materials return to their original dimension when the load is released. Restudy paragraph 9 and then select another response.

583 Another means is used to fasten workpieces to the shaper rotary table. Examine paragraph 7 and choose another response.

584 CORRECT. This dimension is found on the top orthographic view. Each dimension is shown only once, except when necessary to clarify a section or view.

587 C-clamps are not used for this purpose. Scan paragraph 7 again and make another choice.

590 A claw hammer has one end of the head forked for pulling out nails and is one of the most common carpentry tools. Examine paragraph 2a(1) and figures 1, 2, and 3 and then choose another answer.

591 CORRECT. When the driven gear turns once, the driving gear turns 26/39 of one revolution. Thus, 26/39 x 510 = 340 revolutions.

593 Another means is used for distinguishing the tailstock center from the headstock center. The correct answer can be found in paragraph 16a(1) and the note. You should choose another answer.

594 The letter "N" in the front view is represented by surfaces "E," "D," and "C" in the isometric drawing. Refer to paragraph 3 and figures 1, 2, and 3 before selecting another response.

595 CORRECT. The tensile test specimen is mounted in a machine that will exert a pull on the piece sufficient to break the specimen. The load at the point of breaking is recorded by a gage or balancing beam.

597 CORRECT. The blast furnace is used for extracting iron from ore. The resulting iron may be remelted and cast into many different shapes.

598 Lathe speed for machine reamers should be approximately one-half that used for drilling. Become better acquainted with paragraph 35e(3), then choose a different answer.

599 The back rake angle for soft steel is 8° - 17° and the side rake angle is 14° - 20°. Scan paragraph 5 and table I to get the correct angles for laminated plastic. Request that you choose another answer.

600 CORRECT. Most metal cutting bandsaw blades are not capable of being sharpened, but there are some coarse blades commercially available which are made of Swedish steel and have coarser teeth than usual which can be resharpened like wood cutting bandsaw blades.

601 CORRECT. Interlocking tooth side milling cutters and staggered tooth side milling cutters are used for cutting relatively wide slots with accuracy. The staggered tooth cutter is the most efficient for milling slots where the depth exceeds the width.

602 CORRECT. Taper boring is accomplished in the same manner as taper turning. However, only two of the three methods of taper turning are applicable—using the compound rest and using a taper attachment.

603 Your interpretation is incorrect. Please study paragraph 6a and then select another response.

605 CORRECT. This is a typical cutting speed. Specified speeds are approximate and should be readjusted if excessive tool wear is noted.

607 CORRECT. The pitch of a milling cutter refers to the angular distance between like parts on adjacent teeth. The pitch is determined by the number of teeth.

608 Laying out precision angles is the primary function of the bevel protractor. This tool can be laid flat upon paper or the work. Examine paragraph 25a(4) before choosing another answer.

610 CORRECT. One turn of the index crank revolves the spindle 1/40 of a revolution (1/40 of 360°) or 9°. Therefore, 10 complete turns of the index crank will move the index head 90°.

611 CORRECT. The fly cutter arbor is used to support a single-edge lathe, shaper, or planer bit for boring and gear cutting operations on the milling machine.

612 A stress is the force within a body which resists deformation when a load is applied externally. Refer to paragraph 10 again and select another response.

614 This process is not similar to circular sawing. Please turn to paragraph 2a and choose another answer.

615 CORRECT. Some pliers are made for specific jobs such as brake spring pliers, glass holding and breaking pliers, ignition pliers, battery terminal pliers, and brake key and snapring pliers.

617 Did you use the proper conversion table? Read paragraph 2f(5)(b), compute the problem again, and select another response.

619 Your computation is incorrect. Refer to paragraph 13e, recompute the problem, and choose another answer.

621 CORRECT. The grooves (flutes) may be cut into the steel cylinder or the flutes may be formed by twisting a flat piece of steel into cylindrical shape. These drills may be referred to as twist drills.

623 Face milling, also called end milling and side milling, is the machining of surfaces perpendicular to the axis of the milling cutter. Face milling cutters, end milling cutters, and side milling cutters are used for face milling operations. To learn which tool is the best suited for boring, refer to paragraph 26 before making another choice.

624 CORRECT. Forced air for cooling and chip removal is supplied by an air pump in the base of the machine.

625 Cutter bits tipped with tungsten carbide cannot be ground with standard grinding abrasive wheels, but must be ground using a special grinding wheel such as one that is diamond impregnated. Reevaluate paragraph 5g(3) and you will find the correct answer. Select another response.

627 CORRECT. The overall height of the jig block is 1-1/2 units. See the front orthographic view.

628 CORRECT. Forge case hardening, usually used in the field, is accomplished by preheating work to 1,650° F, dipping the work in potassium cyanide or Kasenite, and applying flame until the compound melts. This is repeated until the required depth is attained, then the work is quenched.

629 CORRECT. A tolerance is expressed in the same form as its dimension; that is, the tolerance of a decimal dimension written as a common fraction is expressed as a common fraction.

630 CORRECT. The Shore scleroscope can be transported to the worksite so that hardness tests can be performed on specimens too large to be conveniently moved.

631 The machinists' cross-peen hammer is one of three variations of the peening hammer and is used for special hammering jobs. Refer to paragraph 2a(1) and figures 1, 2, and 3 before selecting another response.

633 The use of this mixture is not feasible. Read paragraph 16d(3) and then select another response.

634 Study paragraph 3; figures 1, 2, and 3; the orthographic views; and the isometric drawing. Note that the letters "J" and "T" (orthographic) represent surfaces "E" and "F" of the isometric drawing. Please choose a more appropriate response.

635 CORRECT. Silicon is one of the chief elements of cast iron and is not used in the charging of a blast furnace.

636 The electric process was not the first to produce large quantities of steel. However, it has two technical advantages: the possibilities of attaining any temperature within reason and of working in a nonoxidizing atmosphere. Study paragraph 30b and select another response.

637 The case-hardening process is not used on low-carbon and alloy steel. Read paragraph 63 before making another selection.

638 Pillar files are similar to hand files only they are narrower. They have one safe or uncut edge. Study paragraph 4e(8) and select another response.

639 This dimension is incorrect. Refresh your memory for reading dimensions by referring to paragraph 7, then take another look at the orthographic views and the isometric drawing before selecting another response.

640 CORRECT. In contrast, if the cutter bit is to be used for heavy roughing where a finished surface is not expected, the nose should be ground with a very small radius (approx 1/64 inch).

642 The perspective drawing may be a simple outline drawing or it may be an actual photographic reproduction with infinite detail and blending of light. Study paragraphs 3 and 4 and figures 1 thru 8, then choose another response.

643 The RPM of the driven gear is faster since it has fewer teeth. Study paragraph 2e(2)(b)(3) again, work the problem again, and choose another response.

644 The left-hand side finishing cutter bit would normally move in another direction. Take a look at figure 3 to get the proper direction. Try another answer please.

647 CORRECT. These extension lines are located on the front and side orthographic views. Whenever possible, extension lines should neither cross one another nor cross dimension lines.

648 CORRECT. The cape chisel is used for special jobs such as cutting keyways, narrow grooves, and square corners.

650 This operation is not correct. Please reread paragraph 16b(8), then select another answer.

651 There is another reason for using a coarse file on thick stock. The correct answer can be learned by referring to paragraph 4d(2). Another response is appropriate.

654 Right-hand cutting is provided by the right-hand roughing cutter bit. This bit is ground like the left-hand roughing cutter bit, only in reverse. Study paragraph 4b(2)(a) to get the correct answer. Then try another choice.

656 The American (National) Standard thread form is the most commonly used thread form in the United States. It has a locking capacity similar to the old Sharp V-thread but will stand greater abuse without damage. Another type thread is especially suitable for vise or jack screws. Request that you choose another answer.

657 The stress test of force within a body which resists deformation when applying a load is common, but is not most often used. Read paragraph 4b again and select another response.

659 The elimination of side thrust on the arbor is accomplished by another means. Read paragraph 4a(4)(a) and choose another response.

661 This is SAE 2320 steel. The first digit (2) indicates nickel steel, the digit (3) indicates the approximate percentage of alloying element (nickel), and the digits 0.20 indicate hundredths of percent of carbon. Study paragraph 25d and e for the correct response.

662 Another type view is used for this purpose. Scan paragraph 5b again and make another selection.

664 CORRECT. Side clearance and end clearance angles of 8° are also required for laminated plastic.

665 Remember that this is a 6-inch micrometer. To arrive at the correct reading: first, record the highest figure visible on the barrel; second, count the number of lines visible between the highest figure on the barrel and the thimble edge; third, take a thimble reading on the line on the thimble that coincides with or has passed the revolution or long line in the barrel. The total of these three readings is the measurement reading. Study paragraph 26e(1) and figure 97, then choose another answer.

666 The bed of the lathe is measured in feet. Another unit of measurement is used for the distance between centers. Scan paragraph 4a again to get this unit of measure. Request that you try another response.

667 Six and one-quarter turns of the crank after each cut would space the gear for more than 12 teeth. Examine paragraph 13e(1)(b), then select another answer.

669 The two-piece pipe dies are other variations of adjustable dies. The two-piece rectangular dies are held in ordinary or ratchet-type diestocks. Collet dies are used with a collet cap and collet guide. Examine paragraph 14b(2) before making another choice.

671 Another type tool bit is more efficient for this purpose. Refer to paragraph 24e for the correct answer. Try another response please.

672 Turpentine is not used for this purpose. Scan paragraph 4e(2) and choose another answer.

674 CORRECT. The combination square set takes the place of a whole set of common tools and is capable of serving as a height gage, level protractor, level, steel rule, depth gage, marking gage, and plumb.

677 CORRECT. The outer jaw, which is adjustable, is made with a small amount of play that provides a tight grip on the pipe when the wrench is turned in the direction of the movable jaw.

679 Remember that when one angle other than the right angle and a side is known, the length of the other two sides can be found. Refer to paragraph 2h(3)(a), recompute the problem, and choose another answer.

682 Laying out precision angles is the primary function of the bevel protractor. The vernier scale is used for accurate angle adjustments and reads to 5 minutes or 1/12°. Study paragraph 23b(1)(a) and then select another answer.

684 A smaller width bandsaw blade would be required to cut a 5/16 to 9/16 radius. Evaluate paragraph 3e(5) and table II before selecting another answer.

685 This is chromium steel containing a very high percentage (5) of chromium alloy and 0.30 hundredths of 1 percent carbon (SAE 5530). Refer to paragraphs 25d and e and then select another response.

687 CORRECT. The rate of spindle speed of the milling machine may be increased from 1-1/2 to 6 times by the use of the high speed milling attachment. This attachment is essential when using cutters and twist drills which must be driven at a high rate of speed.

688 CORRECT. Bench-type drilling machines are used for small drilling operations and are classified as to size by the largest drill that the drill chuck will hold.

690 The term "brittleness" implies sudden failure. It is the property of breaking without warning. Brittleness is the opposite of ductility in the sense that it involves rupture with very little deformation. Read paragraph 10 again and select another response.

691 CORRECT. The sum of the angles of a triangle equals 180°.

45° 27' 01''
43° 43' 04''
88° 70' 05'' = 89° 10' 05''

180° - 89° 10' 05'' = 90° 49' 55''

693 The ram on certain types of milling machines serves another purpose. Reread paragraph 3b(4)(b) and then select another answer.

694 Machinists' levels come in various sizes with adjustable ground glasses and graduated vials with cross levels. They are particularly valuable for leveling shafting, pipes, etc; however, only one plane can be measured at a time. Examine paragraph 19a(1) and choose another answer.

696 Remember the method of obtaining the total reading: first, read the graduations on the main scale; second, locate the line on the vernier scale that corresponds with the line on the main scale; third, add the figures from the readings on the main scale and vernier scale for the total reading. Study paragraph 25c(a) and figure 93, then choose another answer.

697 CORRECT. This method is especially suitable for turning or boring short, steep tapers, or levels. But it is unsuitable for turning tapers greater than 2 to 3 inches in length, because of the limited movement of the compound rest slide on most lathes.

698 Lathe centers are the most common devices for supporting workpieces in the lathe; however, another device is used for the firm connection referred to. Examine paragraph 10a again and select another answer.

699 CORRECT. Notice that both extension and dimension lines are used in this case.

ANSWER SHEET

FOR KEYPUNCH ONLY

001 444
S/C ORD 424 3

NAME ______________________________
LAST FIRST MI

GRADE ____________ SSAN ____________

ADDRESS ______________________________

______________________________ ________
ZIP Code

If this is a new address
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NOTICE

Refer to the instructions preceding lesson exercise question 1 in your study text for information on the use of this answer sheet and the exercise response list. After your selections of choices for all exercise questions have been circled, tear this sheet out of the subcourse, fold it as instructed on the address side, and mail it to the school.

	a	b	c
1.	104	501	536
2.	223	657	595
3.	421	309	243
4.	241	483	527
5.	375	166	612
6.	690	110	427
7.	562	290	420
8.	630	197	463
9.	579	143	661
10.	547	685	342
11.	289	578	231
12.	635	409	235
13.	429	396	636
14.	103	112	529
15.	119	336	178
16.	510	276	452
17.	236	382	524
18.	101	490	362
19.	521	391	369
20.	628	378	426
21.	486	124	582
22.	541	492	242
23.	326	133	597
24.	293	485	637
25.	248	330	288
26.	152	295	423
27.	296	591	643
28.	573	390	432
29.	537	213	256
30.	192	264	117
31.	581	471	341
32.	279	617	324
33.	691	577	292
34.	259	679	298
35.	347	572	129
36.	156	594	278
37.	179	563	491
38.	465	584	188
39.	215	634	482
40.	457	627	356

	a	b	c
41.	437	523	333
42.	349	639	274
43.	277	394	647
44.	539	496	699
45.	113	408	392
46.	522	397	299
47.	191	642	412
48.	358	662	253
49.	500	379	416
50.	116	493	204
51.	164	415	533
52.	629	195	520
53.	311	505	498
54.	167	239	323
55.	304	442	227
56.	631	350	590
57.	677	206	425
58.	389	402	147
59.	316	638	403
60.	194	553	268
61.	393	570	477
62.	284	367	109
63.	207	545	648
64.	422	138	508
65.	615	504	417
66.	145	407	218
67.	580	205	376
68.	621	177	603
69.	468	669	320
70.	134	497	694
71.	385	448	170
72.	200	555	307
73.	674	184	516
74.	567	260	682
75.	228	608	161
76.	372	141	696
77.	549	665	210
78.	444	220	313
79.	688	559	173
80.	100	344	531

	a	b	c
81.	245	405	460
82.	360	440	624
83.	600	365	122
84.	233	626	339
85.	565	282	271
86.	175	684	488
87.	434	150	575
88.	651	363	154
89.	225	474	672
90.	400	136	352
91.	371	535	202
92.	513	266	446
93.	106	654	543
94.	614	262	454
95.	387	518	181
96.	159	374	605
97.	557	127	332
98.	410	619	212
99.	247	451	587
100.	328	551	186
101.	199	301	614
102.	693	131	459
103.	431	607	250
104.	281	480	512
105.	561	286	318
106.	115	507	238
107.	601	222	419
108.	414	190	659
109.	355	611	172
110.	687	439	329
111.	140	381	569
112.	384	667	193
113.	610	118	556
114.	149	447	709
115.	462	335	623
116.	338	666	404
117.	108	224	300
118.	599	664	142
119.	306	121	640
120.	183	470	273

	a	b	c
121.	625	346	515
122.	484	255	399
123.	217	698	436
124.	334	503	139
125.	593	388	291
126.	111	650	331
127.	633	252	479
128.	216	438	528
129.	411	198	671
130.	558	169	398
131.	368	697	275
132.	144	467	656
133.	476	502	123
134.	602	258	450
135.	229	303	598
136.	168	441	305
137.	472	680	125
138.	359	157	576
139.	534	380	244
140.	675	221	401
141.	287	589	606
142.	354	695	189
143.	641	297	499
144.	163	596	386
145.	546	322	257
146.	226	449	514
147.	418	130	609
148.	506	395	193
149.	294	604	406
150.	424	158	353
151.	645	219	548
152.	128	583	254
153.	321	453	676
154.	171	364	620
155.	653	237	464
156.	435	692	146
157.	560	102	337
158.	310	532	270
159.	214	475	571
160.	678	162	348

	a	b	c
161.	428	613	114
162.	201	552	443
163.	509	373	660
164.	180	481	230
165.	357	272	554
166.	586	366	174
167.	343	151	686
168.	120	519	495
169.	626	246	314
170.	487	652	203
171.	285	433	540
172.	618	155	361
173.	473	658	249
174.	211	566	489
175.	182	351	681
176.	308	466	588
177.	538	265	105
178.	445	187	646
179.	153	542	312
180.	234	655	458
181.	670	283	550
182.	302	430	148
183.	574	317	240
184.	165	345	564
185.	325	663	261
186.	622	176	456
187.	592	269	616
188.	208	517	327
189.	585	413	107
190.	377	673	132
191.	135	319	461
192.	683	185	370
193.	494	251	525
194.	544	469	232
195.	267	530	649
196.	668	263	455
197.	315	160	632
198.	137	511	340
199.	568	383	280
200.	478	689	126

CORRESPONDENCE COURSE
# of the
US ARMY ORDNANCE
CENTER AND SCHOOL

EXAMINATION

Ordnance Subcourse No 424 . . . . Machine Shop Practice

Credit Hours . . . . One

Objective . . . . To test your knowledge of material studied in this subcourse.

Suggestions . . . . Before starting this examination it is suggested that you review all lessons used with this subcourse.

Texts . . . . Attached Memorandums

Materials Required . . . . None

(Do not send these pages in - use the answer sheet provided for recording and mailing your solution.)

Requirement—50 Questions—Weight 100—All items are weighted equally.

MULTIPLE CHOICE

(See instructions on answer sheet provided)

1. What should be used as a lubricant when drilling glass?

   a. Soda water
   b. Grease
   c. Turpentine
   d. Oil

2. On what component of the Standard-Modern lathe is the toolpost mounted?

   a. Saddle
   b. Apron
   c. Headstock
   d. Compound slide

3. What design generally reduces the tendency of the cutter bit to chatter?

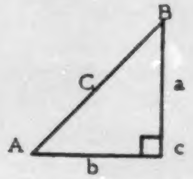
   a. 0° back rake and small side rake
   b. 0° side rake and small back rake
   c. 0° back rake and large side rake
   d. 0° side rake and large back rake

OS 424, E-P1
October 1973

4.

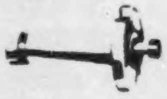
4. If side A of a right triangle (illustrated below) equals 3 inches and side C equals 5 inches, what does side b equal (inches)?

a. $\sqrt{34}$
b. 4
c. 16
d. 8



5. What type of milling machine arbor is indicated by the diagram below?

a. Fly cutter
b. Shell end milling cutter
c. Slitting saw milling cutter
d. Standard milling machine



6. What is the purpose of the secondary clearance angle provided on milling machine cutter teeth?

a. Prevents the cutting teeth from forming overly large chips
b. Provides additional clearance for passage of cutting oil and chips
c. Prevents each tooth from rubbing against the workpiece after it makes its cut
d. Provides a path for chips that are cut from the workpiece

7. What size Phillips head screws should be removed by using a size 3 Phillips screwdriver?

a. 3
b. 8
c. 11
d. 18

8. The purpose of the angular blade guide attachment used on the vertical cutting metal bandsaw is to

a. permit cutting of stock that is too long to clear the machine column.
b. permit internal circular cutting.
c. hold the bandsaw blade for cutting 45° angles.
d. hold the bandsaw blade for cutting 30° angles.

9. What chuck furnishes the most accurate means of holding small workpieces in the lathe?

a. Independent
b. Collet
c. Combination
d. Universal scroll

10. In what position, in relation to the horizontal centerline, must the cutter bit be to perform a parting operation?

a. On center
b. 2° below center
c. 3° above center
d. 5° above center

11. What is a statement of equality between two quantities called?

a. Example
b. Equation
c. Formula
d. Rule

12. What component of a milling machine eliminates the need for a crossfeed dovetail between the saddle and knee?

a. Swivel table
b. Arbor support
c. Ram
d. Saddle

13. Which wrench has an adjustable outer jaw?

a. Single open end
b. Chain pipe
c. Monkey
d. Pipe

14. What part of a drill bit forms a channel which allows the chips formed during drilling to escape from the hole?

a. Web
b. Neck
c. Tang
d. Flute

15. What type vertical cutting bandsaw blade should be used for straight line sawing?

a. Thin
b. Wide
c. Medium
d. Narrow

16. Which quenching method is used primarily on high-alloy steel?

a. Air
b. Brine
c. Oil
d. Water

17. Which soft-face hammer is designed for replaceable faces?

    a. Rawhide
    b. Plastic
    c. Lead
    d. Copper

18. What is the undesirable action called when a clogged file scratches the surface being filed?

    a. Scoring
    b. Pinning
    c. Goring
    d. Gouging

19. How many equally spaced index pin holes are contained in the shaper rotary table?

    a. 12
    b. 8
    c. 6
    d. 4

20. What is the minimum number of teeth of the bandsaw blade that must be in contact with the material at all times?

    a. 5
    b. 4
    c. 3
    d. 2

21. What type drawing is used effectively as an aid in clarifying orthographic drawings?

    a. Central projection
    b. Perspective
    c. Oblique
    d. Isometric

22. The cutting of a surface which is neither parallel nor perpendicular to the surface of the shaper worktable is called

    a. spline cutting.
    b. angular planing.
    c. horizontal planing.
    d. internal slotting.

23. Which type milling machine is characterized by a spindle mounted to a movable housing on the column to permit feeding the milling cutter forward or rearward in a horizontal plane?

    a. Planer
    b. Knee
    c. Ram
    d. Bed

24. What process is used to relieve stresses and increase ductility to a metal that has been forged?

 a. Annealing
 b. Nitriding
 c. Picking
 d. Carburizing

25. What dimension of a lathe is measured in feet?

 a. Overall length of the bed
 b. Diameter of the workpiece that can be swung in it
 c. Distance between centers
 d. Distance the carriage can travel

26. Which feature designates the size of a shaper?

 a. Length of ram
 b. Maximum length of ram stroke
 c. Width and length of shaper table
 d. Distance from the base to the tool slide

27. In what respect is the operation of the vertical bandsawing machine different from most other power machine tool operations?

 a. It is not necessary to convert revolutions per minute into feet per minute
 b. It has sealed bearings and never needs lubrication
 c. It is not as dangerous as other machine tools safety-wise
 d. It has a built-in constant ratio and needs no adjustment

28. Which steelmaking process is used to produce high grade tool steel?

 a. Bessemer
 b. Crucible
 c. Electric
 d. Duplex

29. What is the diameter (millimeters) of the bore of a weapon that fires a 16-inch projectile?

 a. 175
 b. 203.2
 c. 340
 d. 406.4

30. Which type milling operation is the process of machining special contours composed of curves and straight lines at a single cut?

 a. Angular
 b. Gang
 c. Face
 d. Form

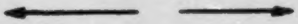
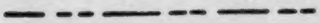
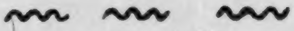
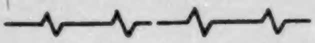
31. What is the square root of 443,556?

a. 612
b. 662
c. 666
d. 673

32. What property of a metal permits it to be permanently deformed by compression without being ruptured?

a. Brittleness
b. Malleability
c. Hardness
d. Strength

33. Which line is used to indicate distance measured?

a. 
b. 
c. 
d. 

34. What type drawing is called the geometry of photography?

a. Cabinet
b. Perspective
c. Oblique
d. Isometric

35. What type milling machine cutter bit is generally used for finishing spiral gears?

a. Hob
b. Angle
c. Convex
d. Concave

36. What are the basic elements that are used in the manufacture of steel?

a. Gray cast iron, silicon, and carbon
b. Alloy of iron and carbon
c. Iron and iron silicates
d. Wrought iron and carbon

37. What type die is usually hexagon in shape?

a. Screw adjusting
b. Open adjusting
c. Two-piece collet
d. Rethreading

38. Which shaper roughing cutter bit usually contains no back or side rake?

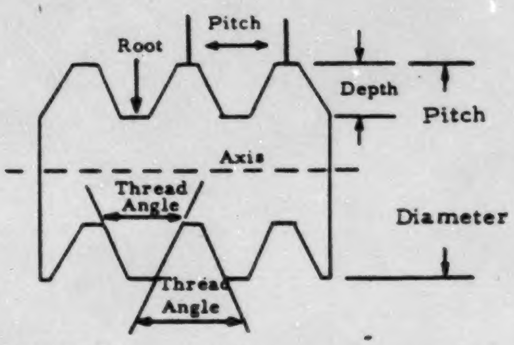
a. Roundnose
b. Angle
c. Left-hand
d. Right-hand

39. What does the geometric characteristic symbol (⊥) indicate on a blueprint?

a. Flatness and straightness
b. Perpendicularity
c. True position symmetry
d. Angularity

40. Which term is incorrectly labeled in the illustration below?

a. Axis
b. Root
c. Pitch diameter
d. Thread angle



41. Which metal is used in the construction of welding electrodes?

a. Titanium
b. Molybdenum
c. Zinc
d. Tin

42. Which statement is FALSE in reference to copper?

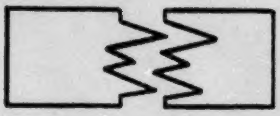
a. Easily machined due to low ductility
b. Chile and Africa are the large foreign producers
c. Commercially pure copper is not suitable for welding
d. Principal commercial use is in the electrical industry

43. What type band file should be used when filing machine steel?

a. Bastard cut, 8 to 12 t.p.i.
b. Short angle or bastard cut, 14-25 t.p.i.
c. Bastard cut, 14-16 t.p.i.
d. Short angle or bastard cut, 10-12 t.p.i.

44. What type break is depicted in the illustration below?

a. Round
b. Rectangular
c. Pipe
d. Wood



45. Which statement regarding the strokes of a shaper is true?

a. Return stroke is slower than cutting stroke
b. Cutting stroke is smoother than return stroke
c. Return stroke is quicker than cutting stroke
d. Return stroke is smoother than cutting stroke

46. What determines the pitch of a milling machine cutter?

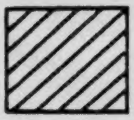
a. Forward facing surface of teeth
b. Number of teeth
c. Width of teeth
d. Length of teeth

47. What pitch hacksaw blade is recommended for general use?

a. 10
b. 14
c. 18
d. 24

48. What type metal is indicated by the symbol below?

a. Babbitt
b. Steel
c. Cast iron
d. White metal



49. What type coolant is especially suitable when machining very hard material?

a. Soda water and soap
b. Lard oil and white lead
c. Borax and trisodium phosphate
d. Soda ash and trisodium

50. What term is applied to the statement of equality between two ratios?

a. Divisor
b. Consequent
c. Antecedent
d. Proportion